BRIQUETTING

BY

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WITH ONE HUNDRED AND SIXTY ILLUSTRATIONS

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PREFACE

—

Although thousands of tons of briquettes are manufactured each year, from all classes of raw materials, the only text book to date published on the subject is the very comprehensive work—"Handbook of Briquetting" by Professor G. Franke, translated from the German by Professor F. Lantsberry.

It is, therefore, thought that a book on the subject, presenting it from the American standpoint, will be of interest.

It is herewith presented—a product resulting from many years' experience in the art on the part of the author's associates and himself.

To those associates—Messrs. Felix A. Vogel, Thomas Gilmore, Jr., William P. Frey, Ellsworth B. A. Zwoyer, Thomas F. Kelly, Wm. H. Waggaman, Carl A. Wendell, George R. Cowan, J. B. McGraw—the deepest gratitude of the author is herewith expressed, for their kindly assistance in the gathering of material and correction of manuscript.

All the companies herein mentioned have, wherever asked, given full cooperation; and, particular thanks are due to the Vulcan Iron Works, Fernholtz Machinery Company, Hydraulic Press Manufacturing Company, M. A. Hanna Furnace Company, Buffalo Slag Co., Lehigh Coal and Navigation Company, the Mines Bureaus of the United States and Canada, Berwind Fuel Company, Wickwire Steel Company, International Coal Products Corporation, New Jersey Zinc Company, Allegemeine Brikettierungs-Gesellschaft, Sutcliffe, Speakman & Company, Limited, Yeadon, Son & Company, William Johnson & Son, Ganz & Company Danubius, and, to the Canadian Peat Committee and the Lignite Utilization Board of Canada.

Figures 31, 32, and 99 are from publications of the United States Bureau of Mines, and are published by permission. Figure 79 was supplied through the courtesy of the American Chemical Society. Figures 85 and 86 are published through the courtesy of Dr. Ernest V. Moore of the Peat Committee. The informa-

tion and prints relative to the lignite briquetting plant at Bienfait, Saskatchewan, have been supplied by Mr. Lesslie R. Thomson of the Lignite Utilization Board of Canada.

To all the above, the sincere gratitude of the author is hereby expressed.

Acknowledgment is also gratefully made to the authors and their articles listed as bibliography at the end of each chapter, from practically all of which was obtained information herein compiled.

ALBERT L. STILLMAN, E. M., M. SC.,

New York City, N. Y.,

January 15, 1923.

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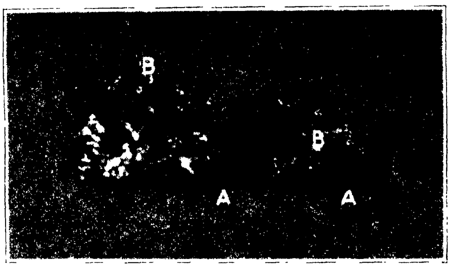

A. Flue dust briquettes
B Fused mass made from flue dust briquettes.

FUSION OF IRON FLUE DUST BRIQUETTES UNDER BLAST

A car of flue dust briquettes made at the plant of the M. A. Hanna Furnace Co., Buffalo. N. Y. (formerly the plant of the Buffalo Slag Co.) was subjected to a heavy rain. It was thought they might return to fine material if subjected to heat and blast. To ascertain the truth, a blast pipe was attached to the car, and a hot blast applied. Almost immediately the briquettes caught fire, and the car was saved with difficulty. When quenched the briquettes were found to have fused into a hard oxide mass. This experiment demonstrates that the fine coke is utilized, and that the flue dust delivers its iron when flue dust briquettes are fed to the blast furnace. (See Chap. XIII)

BRIQUETTING.

CHAPTER I.

RAW MATERIALS.

Briquette Making, a New Engineering Profession Classification of Raw Materials Adaptable to Briquette Making, as to Occurrence and Treatment.

Knowledge, accurate and detailed, along one particular line of endeavor, together with equipment for research along that line, and facilities for learning immediately the accomplishments of others, are to day's requirements of the specialist.

Not very long ago the engineering profession classified itself into mechanical, civil, mining, electrical and chemical. To-day each of these broad divisions contains many specialized subdivisions. Particularly is the chemical engineer growing in importance. The field of conservation, of reclamation of materials formerly wasted, or processing cheap stuff to higher values has brought him new and important opportunities.

Metals, stone, wood, coal and their kin—their production and consumption form a very large fraction of our lives. Large scale economies in their production and utilization mean much to most of us. From mine, quarry, forest and farm the great bulk of humanity's primary raw material is won—and in the winning inevitable degradation occurs. By degradation is meant a reduction in size of part of the material, bringing about a corresponding reduction in value. The culm pile is part of the price of stove size anthracite; saw dust is part of the toll paid for planks. Much of our primary raw material is processed to obtain secondary raw materials—as: ingot metals, obtained from ores; coke and its by-products, from coals. Such processing, practically all of which may be covered by the terms distillation and smelting, in most cases is accompanied by the formation of products and by-products whose finely divided state militates against maximum value. Finally, the manufacturers fabricating secondary raw materials into articles for use employ cutting, trimming and shaping machinery, and here too arises a pile of fine material well suited for salvage.

All this is a field for an engineer—this reclamation—and most of it involves Briquetting—a specialty, and, in America at least, a comparatively new specialty, quite worthy of a life work. And so in chemical and metallurgical engineering arises *the Briquetting Engineer.*

Fig. 1.—Typical Pile of Culm (Coal Dust) in the Anthracite District. (*Courtesy of Vulcan Iron Works*).

WHAT IS BRIQUETTING?

Briquetting is the process of fabricating, through the medium of a press, with or without other operations in connection therewith, fine materials into blocks of larger size but essentially the same composition, for a purpose involving the destruction of the blocks as such, either by direct useful consumption or as a step in a melting or reducing operation.

Here, then, is the answer to that frequently asked question "What is the difference between a brick and a briquette?" If a press makes blocks out of fine material and those blocks go into a building, or enter a long life of usefulness in a pavement, then the press has made bricks or blocks; but if that product is burned, melted, smelted, or otherwise reduced, then, even though shape and size and weight be alike, the press has made briquettes.

Comparatively few of the by-product fine materials of industry lend themselves to brick manufacture. Nearly every one of them is improved by being put in briquette form. The science of briquette making, then, implies the study of the attributes and behavior of a very wide range of raw materials.

Table I classifies these raw materials in respect to their occurrence. This classification shows the field of possible work—most of it still subject to research. There is much for the briquetting engineer to do. It cannot be said that anyone can at a glance advise a method for returning a low value fine residue to a high value larger size—still less the best method. Still—certain of these problems have been adequately solved, that is, commercial equipment has been installed and has made quantity production at a cost well below the selling figure of the briquetted product. Summarized such commercial operations are to-day operating on—

Fuels	Ore and by-products	Metal scrap
Peat	Blast furnace flue dust	Steel
Lignite	Ores of many kinds,	Cast iron
Soft coal	notably zinc and iron	Brass and bronze
Anthracite	ores	Aluminum
Charcoal		
Coke braize		
Saw dust and wood waste		

All these briquettes are either melted, smelted or burned. Fuel briquettes are used in stationary power practice to some extent,

TABLE I. RAW MATERIALS ADAPTABLE TO BRIQUETTING CLASSIFIED AS TO THEIR OCCURRENCE

Products and by-products from the winning of primary raw materials (Mining, milling, forestry, agriculture)						Products and by-products incident to making secondary raw materials (Metallurgical and chemical processes)			By-products and waste from general manufacturing and use		
Organic carbonaceous products (fuel materials)		Inorganic* products and by-products				Organic carbonaceous products (fuel materials)	Inorganic* products and by-products		Organic carbonaceous products (fuel materials)	Inorganic* products and by-products	
Vegetable wastes	Coals	Ore fines of useful metals		Non-metallic mineral products			Metallic	Non-metallic		Metallic	Non-metallic
		for pyro-metallurgical smelting with blast	for electro-metallurgical smelting	for smelting	for other purposes						
Bagasse Straw Husks Shells Grain hulls Seeds Peat Sawdust Wood chips	Lignite Sub-bituminous coals Bituminous slack Semi-anthracite dust Anthracite culm	Ores of iron, zinc, tin, copper, and practically all useful metals (non-precious)	Ores of zinc and others	Limestone (ground), silica, sand and other fluxes Phosphate rock (ground) Phosphate sands Clay	Salt sulphur etc	Charcoal Lampblack Petroleum coke Carbonized lignite Semi-carbonized coals Coke braize	Flue dust from metallurgical operations iron copper etc Filter dust and wet sludge from gas washing in metallurgical operations iron oxide, etc Sludges produced in reducing chemicals anilin sludge, etc Copper cement Pyritic and other fine sinters	Lime soda and other chemicals and fluxes Slags	Wood turnings planings and dust Carbon electrodes breakage Various chars Garbage	Metal turnings, chips, borings needles, "hay," filings, powder, and other light scrap from cast iron steel, yellow brass red brass, German silver, Monel metal, bronze aluminum tin, lead, zinc and other metals and alloys Forge and other scale Jewelers' sweepings	Glass waste Foundry slag

*Not necessarily inorganic in origin

more widely on locomotives, as metallurgical fuel in some instances and very widely as domestic fuel. In the United States and Canada fuel briquettes have especially made great strides lately in the latter field. In the metallurgy of zinc, and especially for the production of zinc oxide, briquetting of the entire ore supply with fuel has proven a striking success. The return of blast furnace flue and filter dusts to the furnace in briquetted form has been shown to be desirable and economical, and there

Fig. 2—Stock Pile of Blast Furnace Flue Dust Wickwire Steel Co., Buffalo, N. Y.

are many installations of briquetting plants for this purpose. In general, where a blast must be driven through a metallurgical charge, fine materials are at a discount, and the substitution of briquettes, providing, as they do, for free passage of the hot blast, pays and pays well. Some materials, like phosphate rock, are too weak in structure to stand up under a pyro-metallurgic blast, and the entire raw supply must be briquetted prior to the smelting operation. Salt, when briquetted alone, meets its destruction by animal consumption—it is a stock feed.

Certain of the materials mentioned in Table I are not briquetted alone, but in combination with other materials. Others may be briquetted alone or in combination as the situation may demand. The fluxes--lime, silica, and others are seldom briquetted by themselves. For certain reducing operations it pays to briquette the material to be reduced (ore or by-products) with carbon and flux. The quantities and percentages of the mixtures are in all cases matters for local study, depending upon the conditions, and the analysis of the materials involved. Certain it is, in the main, that carbon or flux briquetted with an ore or by-

product prior to smelting will have its reducing efficiency largely increased.

We have classified the materials available for briquetting in the order of their progress from their form in nature to the final utilization of the products whose manufacture has demanded them. It remains to classify them in respect to the methods and operations involved in making briquettes. Table II shows such a classification in the order of the events.

The definition of briquetting implies the use of some sort of press. Consequently, all materials subject to briquetting belong in Column 10 of this table. The subject of presses is wide and will be covered in the next chapter. Steel swarf and, indeed, all metal light scraps are capable of briquetting under high pressures without admixture, unless extremely hard, when annealing, outlined in Column 3, is in order. The de-oiling heat

Fig. 3.–Metal Swarf. Long Turnings Requiring Disintegration Prior to Briquetting. (Briquette Pile at the Side is Equal in Weight to the Swarf Pile).

treatment in Column 2 is necessary only to remove the cutting oils and incidental combustible dirt. The pressures involved in metal briquetting have to be high (Chapter II). It is however a fact that in most instances the heat picked up by the metal in the de-oiling or annealing, of itself exerts a beneficent influence upon the briquetting operation.

TABLE II

Preliminary Heat Treatments				Magnetic Separation	Mixing		
Drying	De-oiling	Annealing	Carbonizing Semi-carbonizing Distilling		With water only	With catalytic	With binder
Bagasse Straw Husks Shells Grain hulls Peat Saw dust Wood chips Coal dust Some ores Salt Garbage	Non-ferrous metals (To facilitate removal of iron)	Hard metals especially bronzes (to soften for briquetting)	Straw, husks, shells, hulls, wood, chips, soft coal dust, lignite, garbage (Above operation with wood and vegetable matter produces charcoal See Col. 8) (Semi-carbonizing of soft coal produces semi-coke See Col 15) (Carbonizing of lignite produces a peculiar charcoal-coke, excellent for briquette fuel)	Non ferrous metals (Iron must be removed from these metals prior to briquetting)	Salt (when permissible) Cast iron Ores and by-products (when mixed with flux of lime, soda ash and the like)	Blast furnace flue dust Blast furnace filter dust Flux and ores when mixed with the above	Charcoal All classes of coal Ores not treated as in 6 and 7
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

Mastication	Pressing	After Heat Treatment of Briquettes				
		Drying	Cooling	Steaming	Carbonization	Distilling
All classes of material in columns 7 and are often masticated prior to briquetting	All material to be briquetted (Light metal scrap, clean and dry is briquetted by pressing without pre-treatment or after treatment	Some kinds of coal briquettes and some kinds of ore briquettes	Most briquettes cool and set properly in atmosphere Coal briquettes are sometimes cooled artificially before storing	Ore and by-product briquettes where lime is used as a binder harden quickly in steam	Soluble binders in briquettes are sometimes rendered insoluble by carbonizing	Charcoal briquetted with wood tar (Tar can be recovered by distillation) Semi-carbonized coal briquettes. (Complete distillation after briquetting recovers by-products) (Carbocoal process) Much research now being done in this direction in all classes of fuel briquettes
(9)	(10)	(11)	(12)	(13)	(14)	(15)

Practically all organic substances contain large quantities of moisture. Peat runs as high as 90 per cent when freshly mined, running down to 35 per cent after exposure to the atmosphere. Indeed this moisture forbade the fuel utilization of peat. Lignite averages 30 per cent moisture but many factors argue in favor of distillation in a retort as a preliminary to briquetting this interesting fuel. Coal in finely divided form generally arrives at the bri-

FIG. 4.—Typical Lignite Operation (Johnson Fuel Co., Scranton, N. D.). The Briquetting of Lignite or "Braunkohle" Usually Involves the Entire Mine Output, as Contrasted with Anthracite and Bituminous Coal Operations, where Fine Size Wastage only is Involved

quetting plant with 10-20 per cent moisture, which is usually reduced to less than 3 per cent and the raised temperature of the coal is in most processes beneficial to the final product. Vegetable matter is excessive in moisture, and a drying, even to the point of carbonization, is of advantage.

The winning of by-products by distillation from all manner of vegetable kingdom refuse (Column 4) is an extremely important work, now undertaken seriously in many quarters, both with and without the briquetting of residual charcoal. The

United States Government Bureau of Mines is at present engaged in investigating the distillation of waste straw and kindred products. The Arthur Maas Laboratories have devised a rotary retort for the distillation of nut shells, the residual charcoal being used for poultry feed. An extension of these enterprises would enormously increase the field of charcoal briquetting. Rice hulls are similarly under investigation by rice mills in Louisiana.

The distillation of the lignites of Saskatchewan followed by briquetting of the residual carbon has been brought to a successful conclusion by the Lignite Utilization Board of Canada, and

Fig. 5—Oil Carbon from Oil Gas Manufacture—a Raw Material for Fuel Briquetting in California. Los Angeles Gas and Electric Corp., Los Angeles, Cal.

the first plant is in course of erection at Estevan, Saskatchewan, Dominion of Canada (Chapter IX). The International Coal Products Company has devised a system, known as the Smith Process, for partially distilling soft coal, briquetting the semicoke produced, and finally distilling the briquettes, (Column 15) winning a good yield of by-products and making a firm, smokeless residual briquette (Chapter XII).

When we come to the matter of admixtures,—Columns 6, 7 and 8. There are in reality three great classes of materials.

1. Materials requiring no admixture, or at most, a slight dampening, prior to briquetting.

To this class belongs all metal swarf, or light scrap.

Sawdust, and wood waste, which requires heat treatment but no binder.

Dried peat, and other dried vegetable matter.

Salt, phosphate rock and phosphate sand.

Ores mixed with reducing flux, as lime or soda ash.

Petroleum coke and lamp black.

It is generally recognized that practically all materials can be briquetted through the medium of pressure alone, provided that pressure be great enough. It does not pay, however, to spend money realizing the great pressures used in metal swarf briquetting for comparatively cheap ores and coals Peat and sawdust properly pre-treated, briquette without binder at low pressure.

2. Materials, which, by the addition of a small quantity of reagent (generally called catalytic) become self-cementing and briquette satisfactorily under very low pressures.

In this class is found the cheapest cost-per-ton of all briquetting operations. Blast furnace flue dust and some similar metallurgical products take on this self-cementing quality through the addition of less than one per cent of comparatively inexpensive calcium chloride, or ferrous sulphate.

3. Materials requiring a binder to briquette properly at reasonable cost.

In this class are found all coals, including charcoal; all ores, not found in Class 3; coke braize, sand and certain other fluxes, lime (if slaking with water is undesirable).

Finely divided metals, jewelers' sweepings, scale, and glass wastes.

A full discussion on various types of binder is found in Chapter VI.

This third class, containing, as it does, all classes of coal briquettes, is of first importance. It is not too much to say that to the majority of persons the term briquette means a compressed block of coal fuel and nothing else. By far the greatest tonnage of briquettes in the world is that where fine material is mixed with binder. The resulting mix is much improved by mastication, a process invented in Holland, and introduced in the United States within the last five years. By mastication is meant the intense kneading action produced by grinding the mix under ponderous rollers. The machine for the purpose, the masticator or edge runner (Fig. 114, Chapter X), is simply a heavy iron

trough or basin in which revolves a shaft carrying two great rolls, each followed by a plow for discharge. In the case of most classes of coal this grinding-in results in a dry, pulverulent mix, thoroughly binder-permeated, which, after pressing, becomes at once a hard and satisfactory briquette.

After pressing, briquettes of Class 1 and most of those made from coal are ready for use. Sometimes, especially in summer, coal briquettes are benefitted by a cooling operation before going into storage. The flue dust and ore briquettes of Class 2 require 24 hours standing to season them. Briquettes in which lime or magnesia has been used for binder will harden slowly in the air; but will harden more rapidly and set more strongly if given several hours in an atmosphere of dry steam. Coal briquettes made with binders involving carbohydrates, as starch, and the like must be baked and even carbonized, to secure waterproof quality. By baking is meant a heating operation involving a higher temperature than mere drying to make the carbohydrate practically insoluble. In carbonizing the heat is carried much higher, removing the hydrogen and oxygen elements from the carbohydrate binder, and leaving the residual charcoal (of the binder) to hold the coal particles together. Such briquettes are excellent when properly made, but the mechanical difficulties are many.

The distilling of certain classes of briquettes is assuming increasing importance. The work of the Smith Process (Carbocoal) has already been mentioned. Another interesting phase of this kind of work is the manufacture of charcoal briquettes. The binder usually to hand when fine charcoal is made is wood tar. The combustion of wood tar is accompanied by very disagreeable fumes, very undesirable in so high class a fuel. It has been found feasible to retort the charcoal briquettes, winning back a part of the wood tar therein contained and carbonizing the rest, resulting in a dense, smokeless, and altogether excellent briquette, superior in fact because of its density, to block charcoal from the same wood. (Chap. VII).

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CHAPTER II.

BRIQUETTE PRESSES

The word "Briquetting" by definition implies the use of a press in obtaining the product. Like all other industrial processes, modern scientific briquette-making machinery has evolved from primitive methods, some of which survive to-day. In central Europe briquettes of a sort have been made by mixing air dried fuel—coal, lignite, peat, with water—to which clay or glue may or may not have been added; kneading the material with the feet; ramming into rectangular or cylindrical molds; and, upon removal therefrom, allowing the briquettes to set or harden in the air. This product is decidedly home made, and seldom travels far from its point of origin. The modern product is made on highly specialized presses.

Broadly speaking, there are but two classes of briquetting presses, based upon the methods of applying pressure:

1. The mold and piston type,
2. The roll type.

In Class 1 the material, after proper preparation, is packed in a mold and pressure applied by means of a piston, or set of pistons. The primitive method above mentioned is in this class. All presses capable of exerting high pressures are included as well. In general, this class of press has higher operation costs than those in Class 2, but, through realization of higher pressures, can give a denser product.

The following are the requirements to be fulfilled in the design of a briquetting press, whatever material is involved:

1. Proper-feeding method, automatic if possible.
2. Uniform pressure—to obtain uniform density (best obtained in reciprocating presses by two plungers working on opposite sides.)
3. Large capacity.
4. Minimum waste of raw material.
5. Simplicity.
6. Ruggedness.
7. Efficient safety devices.
8. Accessibility of parts.
9. Small depreciation and facility to repair.

10. An efficient discharge for finished briquettes.

11. Small labor requirements for operation both as to numbers and skill.

In Europe piston and mold presses are used extensively for the briquetting of fuel. In the United States the general practice in coal briquetting has called for presses of the roll type. There are exceptions, notably on the Pacific Coast, where piston and mold presses are used for the briquetting of "carbon black" and lignites. While the indications show possibilities for each type of press enjoying a wider range of usefulness, the present practice in the United States is along the following lines:

1. Piston and mold presses	Hydraulic pressures 10-35,000 lbs. per sq. in.	For metal, swarf and salt
	Toggle and mechanical pressures up to 10,000 lbs. per sq. in.	For ores and the like
2. Roll presses	Pressures 2,500-6,000 lbs. per sq. in.	For fuel, ores and by-products

The classification of briquetting presses on p. 15 is according to types, and cannot be taken as a full catalog of briquetting presses. There are several makes of most of the types of press mentioned, with minor variations. The list, too, has omitted some types that have been superseded. Where known the designer's name has been used as characterizing the type.

DESCRIPTION OF PRESSES—PISTON AND MOLD CLASS, HYDRAULIC.

The Ronay-Gilmore Press.—This press consists of upper and lower platens connected by three columns on one of which is mounted a horizontal rotating table. A main pressure cylinder is set in the lower platen and at the centre of the triangle formed by the three columns. Cylinders for the packing, ejecting and table turning rams are fastened to the upper platen. The rotating table contains six molds either 5 or 6 inches in diameter each. Table rotation is performed automatically by means of hydraulic valve gear. Three of the molds are simultaneously subjected to the various operations of packing, pressing and ejecting, while the alternate three are idle.

TABLE III.

Piston and Mold Type			Rotary Presses	
Hydraulic briquetting presses	"Fall" presses	Mechanical and toggle presses	Material fed vertically	Material fed horizontally
Primarily briquetting for metal swarf and light scrap Ronay-Gilmore type Gilmore type Stevenson-Little type Duryea type Jacomini type	Dorstener type	(a) *Primarily for briquetting ores, dusts and mineral slack* Schumacher type White type Revolver type Tigler type Sutcliffe type	Belgian type Zwoyer Universal type Komarek type Mashek type	Allen-Hutchinson type Jenkins type
	Gröndal type	(b) *Primarily for briquetting fuels* Couffinhal type Meguin type Exter type Fernholtz type Renfrow type Rutledge type Schorr type Ladley type *The last three types may be termed rotary plunger presses*		

NOTE:

A third class—namely—Peat Machines—are described in the Chapter on Peat (CHAPTER VIII).

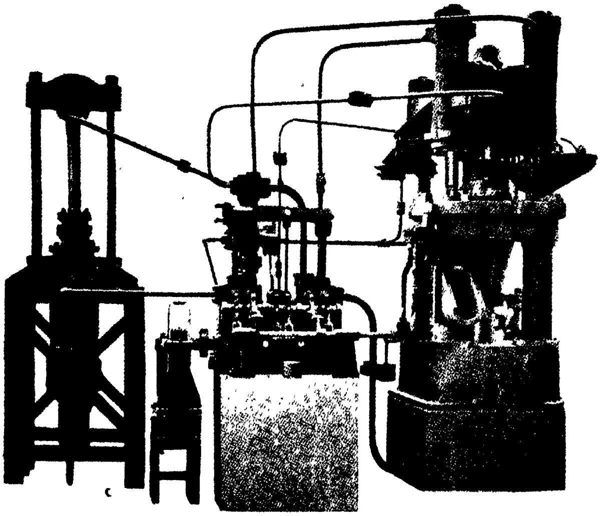

Fig. 6.—Ronay-Gilmore Hydraulic Briquetting Press for Briquetting Metal Swarf.

In the first sector the mold is filled with swarf from a filling hopper and the contents are then subjected to the action of the packing plunger. After the filling and packing are completed, the table is revolved 60°, which brings the mold to an idle position, where it awaits the filling of the succeeding mold. This filling completed, another 60° revolution carries the first mold to the pressing position, directly under a stationary counter plunger and over the pressure plunger. Pressure is admitted at the proper time by means of the valve gear. The lower plunger is forced upward and against the chips in the mold. The friction of the chips on the wall of the mold causes the mold to lift. This movement of the mold has the effect of two moving plungers, thus not only materially reducing the wear on the mold, but also increasing the hardness of the upper side of the briquette, usually weak in briquettes made by other types of press. A downward pressure is exerted by means of counterweights, which serve to assist the mold to retrieve into position in the table. The pressure at this position is applied in two stages, the valve gear first admitting the accumulator pressure, and so diminishing the volume of

the chips contained in the mold considerably; this is followed by the admission of the intensifier pressure, which completes the formation of the briquettes.

The power required to form a briquette is conserved by first applying accumulator pressure at the packing ram on a small diameter piston, and then applying the accumulator pressure at the pressing plunger on a large diameter piston, and following with the intensified pressure on the same piston. So the volume of the material is reduced, so far as possible, with the low pressure and with a minimum of high pressure water.

The slow building up of pressure by stages prevents the entrapment of air. The formation of compressed air pockets being eliminated there is no tendency of the briquette to expand with consequent disruption.

The pressure is brought up to a maximum, and is held long enough to overcome the elasticity of the metal and allow it to take a permanent set. The pressure being withdrawn, the mold is again advanced to an idle position, and thence to a position directly under the ejecting piston. At the proper time the valve gear admits pressure to this piston, which, by a downward stroke, ejects the briquette into a discharge chute.

When 6 inch molds are used, a final pressure of approximately 23,000 pounds per square inch is applied on the briquette, and when 5-inch molds are used, a pressure of 33,000 pounds per square inch is attained. The packing, pressing and ejecting operations are all performed simultaneously, and when the pressures are removed, the pistons retrieve automatically, their return side being under accumulator pressure. After being so retrieved, pressure is admitted to a piston, actuating a rack, which in turn, by means of a gear and clutch, revolves the table through a 60° arc. The table is brought to a stop at the proper position by means of stops mounted on the periphery of the table, which engage a swiveled arm, directly connected with the rack. This arm is mounted on one of the three main posts of the press.

Operating Valves.—Three double valves, mounted on a suitable base, are actuated at a pre-determined time by means of a cam shaft, which, through connecting levers, open and close the several valves. This cam shaft is operated through a worm wheel, which is driven by a motor. Accumulator pressure (usually 1,500

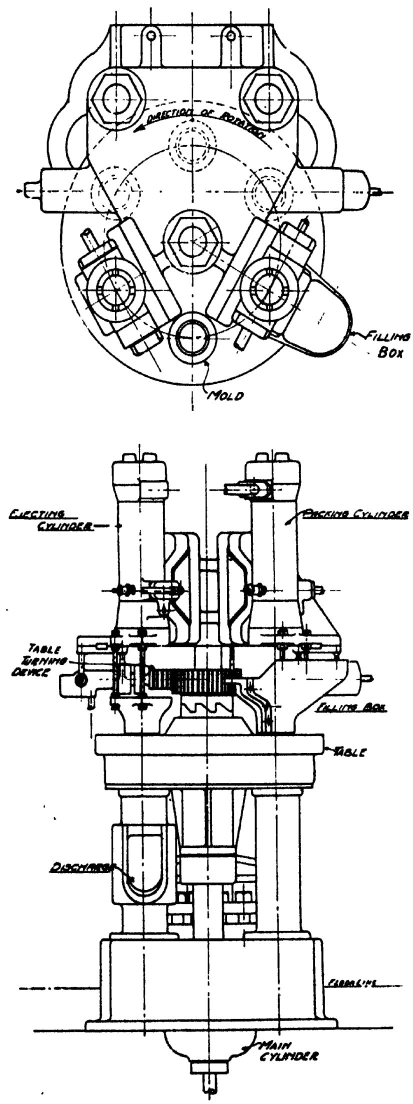

Fig. 7.—Plan and Section—Ronay-Gilmore Briquetting Press.

pounds) is admitted through a simple check valve to a double balanced inlet and discharge valve, which in turn admits the pressure to the pressing and to the ejecting cylinders. Another double-balanced valve admits the accumulator pressure directly from the line into the packing cylinder and low pressure side of the intensifier. The high pressure side of the intensifier is directly connected between the check valve and inlet valve to the press cylinder and ejecting ram, thus permitting the intensified pressure to follow up on these two cylinders. After these respective operations are completed, the inlet valves are closed and the discharge valves opened, thus allowing the pistons to retrieve. A small double-balanced valve actuates the table after these pistons have retrieved. A safety device is provided which prevents the opening of the pressure admission valves to the packing, pressing and ejecting pistons, in case the table stops before the molds are in position under the rams.

The hydraulic machinery necessary for the operation of this press consists primarily of a pump and accumulator.

Four to five briquettes per minute are produced, their thickness depending upon the bulkiness of the material being pressed. An initial filling depth of 20½ inches or more is provided between the bottom of the mold and the end of the packing ram.

The following table shows the capacity in a general way when briquetting cast iron borings, steel turnings and brass turnings respectively for both 5-inch and 6-inch molds.

TABLE IV.

Material	Thickness of briquette Ins.	Weight of briquette Lbs.	Lbs. briquette produced per hr.
6-In. diam. briquettes			
Cast iron borings	5 to 8	25 to 40	6,000 to 9,600
Steel turnings	3 to 5	15 to 25	4,000 to 6,600
Brass turnings	1 to 5	6 to 30	1,500 to 7,500
5-In. diam. briquettes			
Cast iron borings	5 to 7½	16 to 25	4,000 to 6,000
Steel turnings	3 to 5	10 to 16	2,400 to 4,000
Brass turnings	1 to 5	4 to 20	1,000 to 5,000

The Gilmore Type Press.—The press is of two-post horizontal construction. The working end is of steel designed for the required pressure, which is transmitted by a large diameter plunger.

Two pull-back pistons, outside packed, are connected to the main plunger by means of a cross-head. The head block contains the mold—steel, bushed with hard iron, cylindrical in shape, of a diameter and length conforming to the size of briquette desired. The large size press specifications usually call for a 6-inch diameter mold, and the small size press for a 4-inch. The back plate of the mold is movable, and the movement can either be controlled by hand or attached to the hydraulic system. In the lower portion of this back plate is a circular opening of diameter equal to that of the mold. Between the mold and the water end of the press is the hopper, purposely made as long and as wide as possible in order that turnings of great length may be accommodated. (The facility of feeding large size turnings is an excellent feature of horizontal press construction).

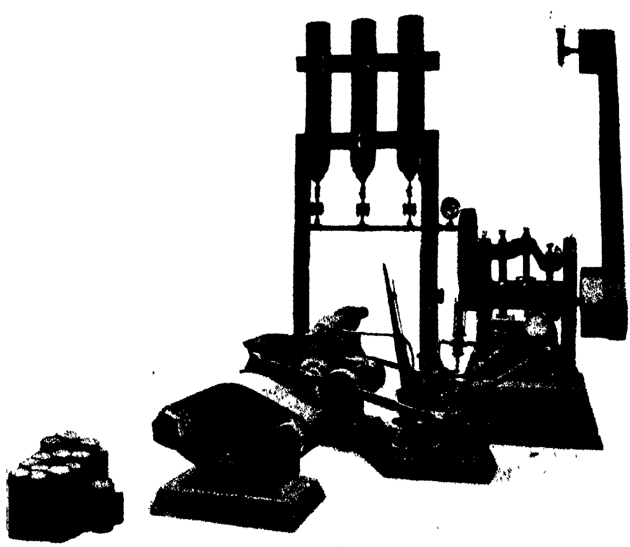

Fig. 8.- The Gilmore Horizontal Press C. Type.

In brief, the cycle of operation is as follows: The piston is drawn back, and the hopper filled with turnings. The throttle is opened, and the advancing piston pushes the turnings into the mold and packs them. The full pressure is built up to the maxi-

mum desired, and the briquette is formed and set. The pressure is released and the rear plate of the mold raised, bringing the circular opening to the rear of the mold. Light pressure is again admitted, and the piston ejects the finished briquette.

This press is the simplest in design and lowest in cost of the hydraulic metal briquetting presses. It is adapted to use in brass and iron foundries, especially for brass chips, and for cast iron borings. In the latter field it is desirable that the hydraulic lift and double pull back be used, whereby a capacity of two briquettes per minute, or 750-1,000 pounds per hour, may be obtained, on the smallest size press.

About 40 horsepower is required to operate the smaller size. The press is made by the General Briquetting Co. in two sizes B and C.

	B press	C press
Cap per hr. Tons	1¼-2	¼-½
Wt. lbs.	18,000	12,000
Size of briquettes, Ins.	6 (usually)	6 (usually)

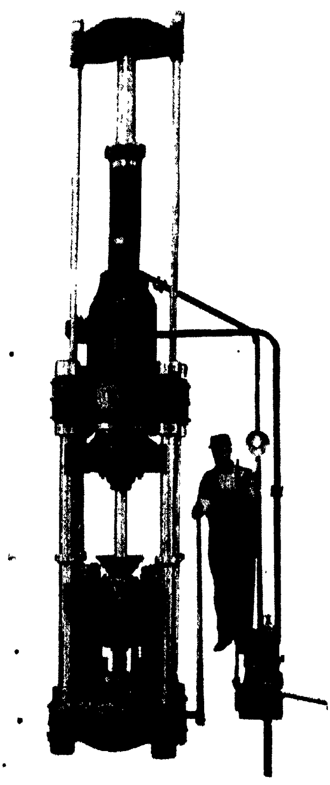

Fig. 9.—Stevenson-Little Vertical Hydraulic Metal Briquetting Press.

The Stevenson-Little Press.—This press is of the inverted type with a single auxiliary pull back cylinder above the main cylinder, which operates the platen by means of a yoke and pull-back rods.

In this press the equipment for molding the briquettes in the press consists of a mold which has a liner forced into it. This mold is supported by four stems on large rods. The springs are compressed sufficiently to support the weight of the mold, and nuts serve to keep

the mold from being forced off the ends of the rods. A sliding die block carrying the lower plungers rests on the press base, and, when in position for pressing, supports the plunger with its upper end. About one-eighth inch below the bottom of the mold on the plunger is a light spring, supporting a ring, which is bored to fit the plunger. This spring holds the ring firmly against the bottom of the mold, preventing any of the material, which may be very fine, from leaking through while the mold is being filled.

The mold is filled by means of the conical hopper and when ready for pressing, the plunger descends through the hopper. As the material becomes denser its friction and adhesion on the side of the mold causes the four springs on the sides of the rods to be compressed, lowering the mold over the plunger, while the ring is depressed against the spring. When the pressure is released the mold assumes its natural position and the block is moved to the back of the press by means of a lever. On the necessary downward movement of the press ram the briquette is ejected.

This press is operated most satisfactorily from a high and low pressure accumulator although it can be operated from high and low pressure pumps. It is made by the Hydraulic Press Company.

Duryea Metal Briquetting Press.—This design of press, although somewhat complex is exceedingly interesting, because it carries the only application of the principles of the internal combustion engine to briquetting practice. The combination of hydraulic pressure and explosive force is very ingenious. It necessitates a closely calculated timing device. The timing is effected by six cams mounted on the same cam shaft and carefully designed that the various operations controlled by them occur in proper sequence. The first cam operating through a rocker arm and push-rod controls the internal combustion engine exhaust valve. The second cam similarly operating controls the inlet and sparker of the same engine. The third cam operating through a series of arms and springs controls the upper ram over the mold. The fourth cam operates the mold feed. The fifth cam operates the ejecting device. The last cam (sixth) operates the hydraulic valve, whereby the hydraulic pressure is admitted or closed to the upper ram.

One section of the base supports the cam shaft and the other

the briquetting press proper. This base consists of a rectangular two-piece casting. The upper frame of the press proper is made up of a cylindrical casting supported by four columns. A mold is located at the center and near the base of the fourth column, and in the upper cylinder the briquetting ram plunger operates. The mold is supported by studs. Below the mold a block is mounted carrying an upwardly projecting counter plunger whose motion is used to eject briquettes from the mold. It will be seen that the briquetting operation, therefore, consists primarily of a mold with pressure plunger working from above and counter plunger working from below.

The feeding device consists of a horizontal bored casing, set at the side of the mold. In the casting a charge carrier operates reciprocally. Material is carried by gravity from the hopper down the feed pipe into the casing, and is thrust automatically into the mold by the charge carrier actuated by cam No. 5.

The cycle of operation is as follows: The charge of material is shoved into the mold by the charge carrier, as described and on

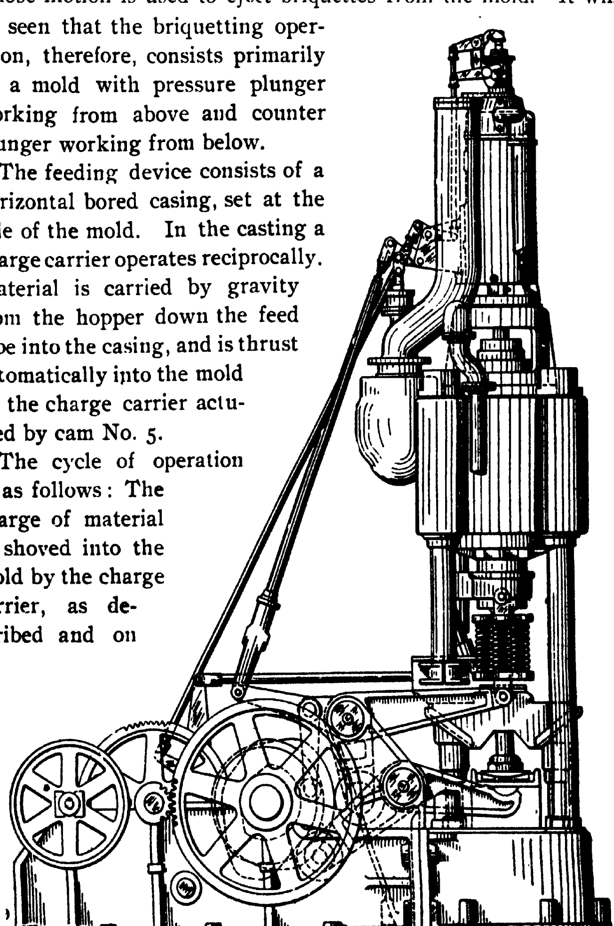

Fig. 10.—Duryea Metal Briquetting Press. Diagram of Operation.

completion of the feed the charge carrier withdraws to a position beneath the feed pipe. Now the second cam operates a bell crank and admits fluid under pressure into a conduit in the upper ram cylinder, forcing that ram downward upon the charge in the mold. The pressure at this point is such as to give efficient packing to the charge, being about 2,000 pounds per square inch. Meanwhile the internal combustion piston is at its highest point, being above the fluid conduit, directly over the ram and separated from the ram by the fluid. By the action of cam No. 6 the ram cylinder valve admitting fluid is closed, and the action of cam No. 2 opens the valve that admits explosive mixture into the internal combustion engine. The continued turn of cam No. 2 serves to close the gas mixture inlet valves, and to actuate the sparker push rod. The gas vapor charge is ignited, generating heavy pressure against the piston, which is forced downward against the fluid in the conduit. The pressure thus transfers to the pressure ram, which is forced downward, delivering the force of the explosion to the charge of metal chips in the mold. The lower end of the gas engine piston is enlarged, and, in its highest position fits into a recess, into which the water is forced, since this piston head clears its outer edge in its descent. By this action and by the continued descent of the plunger, with the continual increase in fluid displacement, a great final pressure is realized in the ram cylinder, which final pressure serves to finish the briquetting operation.

The operation of cam No. 2 now opens the exhaust valve of the power cylinder, and the change in pressure balance forces the power piston upward to its original point. Cam No. 6 opens the hydraulic valve in the ram cylinder and the excess of fluid returns to its reservoir. Meanwhile cam No. 3 raises the ram from the briquette clear of the mold, and cam No. 5 operates to raise the counter plunger at the base of the mold, thereby raising the briquette. The new charge, pushed forward by the feeding valve, serves to eject the briquette. The cycle is then complete.

This press is equipped with a safety device whereby the ignition fails to work if the charge of material in the mold is insufficient.

The Duryea press has been installed in Chicago at the plant of

the American Block & Ingot Company, at Waterbury for the Eastern Briquetting Company, both installations being for the purpose of briquetting metal scrap. Another installation has been recorded, namely in Kingston, Tennessee, for making blocks of charcoal fines. (See Chapter VII).

The Jacomini Press. The novel feature of this press lies in the

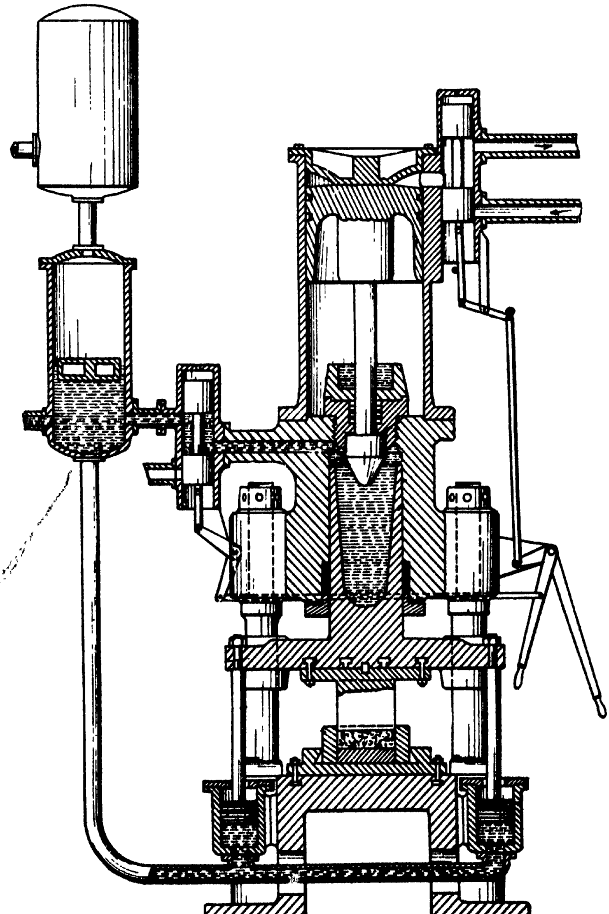

Fig. 11.—Jacomini Metal Briquetting Press. Diagram of Operation.

method of intensifying the pressure stroke during the briquette formation. The power stroke is steam driven, but the pressure is transmitted to the metal chips via a hydraulic cushion.

The press is vertical. Filled molds are placed successively under the ram, and after the operation the finished briquettes removed by hand or mechanical means. A mold, properly filled with material, is placed under the ram by the operator. By means of a lever controlled valve, fluid is admitted under pressure into a recess in the upper die member. The fluid is supplied under pressure by a pump. The admission of the fluid forces the ram upon the work. The ram and its cross-head are held in position by four columns, serving as guides. On these four columns rests the operating cylinder of the press.

After the ram has descended upon the work, and initial pressure has begun, the operator closes the fluid inlet valve, and opens a steam valve, admitting live steam to the upper part of the operating cylinder—this upper part being in effect a steam chest with a piston plunger. The upper extremity of the plunger is secured to a piston against which the steam drives. The lower extremity of this plunger is provided with an enlarged head, the upper portion being cylindrical and fitting into a cylindrical recess in the base of the steam cylinder, and in contact with the fluid in the ram. The plunger is forced downward by the steam, and the enlarged head, advancing into the fluid, augments the pressure against the work steadily until it clears the recess in which it was contained. When this occurs the capacity of the water cylinder in the ram is suddenly increased, and the resistance to the plunger disappears for an instant, until the mass of the descending plunger balances the increase in space so provided. In this instant the plunger therefore jumps and acquires a very considerable velocity, which is transmitted to the ram, giving the effect of a hammer blow, and results in a great increase of pressure on the metal in the mold.

On the completion of the descent of the steam plunger the operator reopens the fluid valve, and the fluid, now under extreme pressure, returns to its reservoir. The trapped air pressure in this reservoir is transmitted through a pipe to the base of the machine, where fluid is forced into the four cylinders, driving against

pistons connected with the cross-head of the ram. The ram is thus raised from the work to its original position, the mold containing the briquette is removed, and a new mold, filled with metal chips is placed in the working position.

When the operator reopens the fluid valve to drive the ram down upon the charge, the fluid pressure drives the steam cylinder back into its recess.

The Jacomini press has made excellent briquettes from such stubborn material as cast iron borings. One installation is recorded in Cincinnati, Ohio.

DROP OR FALL PRESSES.

The Drop or Fall type of press consists essentially of molds, with a feeding device to pack the material into the molds; and a plunger set above the mold. The plungers are lifted at regular intervals by cams mounted on a horizontal shaft, and, released by gravity, fall upon the material in the mold. The material is subjected to one or more plunger drops, and the pressed material is then lifted from the mold by an ejection device operating from below. After the briquette is clear of the mold sides it is shoved forward, clear of the plunger path, to a receptacle in front of the press. Presses of this type are used on material whose setting requires the assistance of a pressure greater than that realized by the ordinary clay brick forming machines.

The Dorstener Press.—One of the best known of this type of press is the Dorstener, made by the Dorstener Eisengiesserei und Maschinenfabrik AG Hervest-Dorsten, Germany.

In back of this type of press is a feed hopper, provided with a gate. The molds are filled by means of a charging box moving reciprocally from the base of the hopper over the molds. This motion serves to push, from the mold to the front of the press, the finished briquettes just raised from the mold. The plungers are raised to three times their height and, being released, fall freely. The plungers on one size of this press weigh 900 pounds each (app.) They are lifted by cams mounted on a shaft carried on the frame of the press. It is customary to submit each brick to three plunger drops, before ejection. The ejection device consists of a lever, operated by a cam, which at the proper

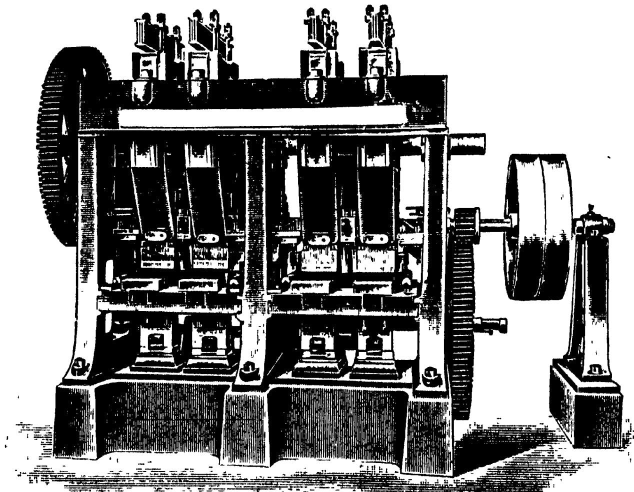

Fig. 12.—Dorstener Press.

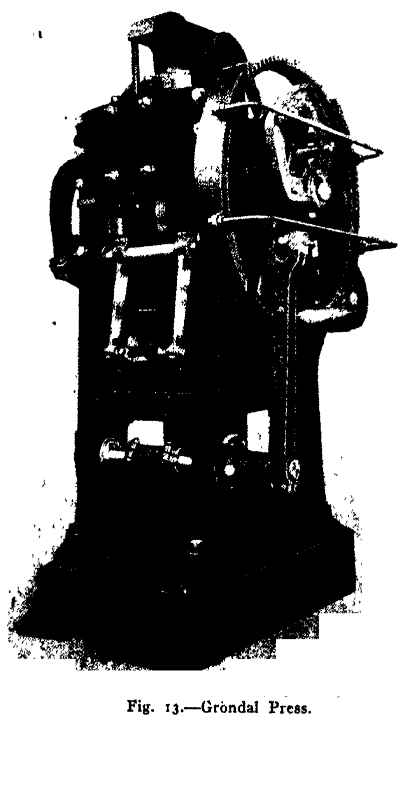

Fig. 13.—Gröndal Press.

time raises the lower plunger which forms the bottom of the mold, and places the brick in position for the thrust of the feed box. The feed box is returned to the feed position after the first of the three falls of the plunger hammer. The molds are kept heated with steam to prevent sticking. The mold liners are easily renewable. At thirty-nine revolutions of the shaft the press makes 2,100 brick per hour. The horsepower required is between 3 and 4.

The Gröndal Press.—The Dorstener press is essentially a brick press, but has been used for briquette making. The Gröndal press (Fig. 13) operates under essentially the same principles, and has been installed in many of the iron ore briquette plants operating the Gröndal process, especially in Sweden.

TOGGLE OR MECHANICAL PRESSES.
Primarily for Briquetting Ores, Dusts and Mineral Slack.

The Schumacher Type Press.—This press is of a toggle action, belt-driven type, designed for high and uniform pressures for the briquetting of fine ores, concentrates, flue dust and the like.

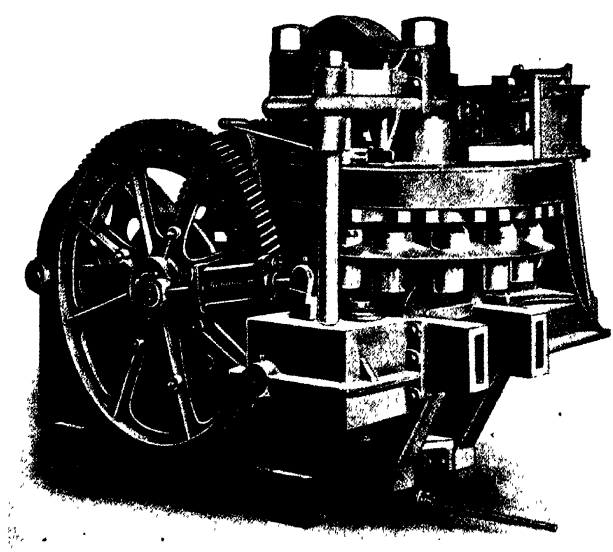

Fig. 14.—The Schumacher Toggle Rotary Table Briquetting Press.

The press is mounted on a double girder bed-plate, which, with cross-girders, serves as the lower platen of the press. The upper platen is held in position by two tie bolts and separators, one of which serves as the journal or axis about which the mold and plunger platen revolves. This platen has pockets to receive twelve cylindrical mold liners, 7½ inches in diameter, each being provided with a plunger serving as a bottom for the mold, the upper side of the mold being sealed at the pressing position by a safety compression block attached to the upper platen.

The main plunger, mounted in the lower platen between the two tie bolts, engages each of the table plungers successively, and is actuated through a connecting strap by the main toggle lever, the fulcrum of which is carried by an oil cylinder piston mounted between the double girders of the press. The only outlet from this cylinder is connected to a nitrogen gas flask. The combination, serving as a cushion and relief, insures absolutely uniform pressure on the material to be briquetted, regardless of the amount of the material in the mold. Thus, the best and most suitable pressure for any material can be applied by varying the initial pressure in the nitrogen flask.

The swivel end of the toggle lever is connected to a crank shaft actuated by a belt drive through heavy gears mounted on the two press girders.

The mold platen is driven by means of a "Geneva" movement and is locked in position during the mold filling, pressing and briquette discharge operations. The feed box is mounted on a stand, directly over the table, and the molds are filled as they come into position under it by a set of revolving paddles. The mechanism for discharging the briquettes from the molds consists of an auxiliary plunger, mounted in a side frame, which is actuated through a connecting strap by a bell crank, which is in turn actuated by means of a connecting rod, provided with a spring takeup, attached to one of the main driving gears. This auxiliary plunger engages in succession the mold plungers, forcing the briquette up until it clears the mold. The briquette is then pushed off the top of the mold plunger by a cross-head to the space between the molds. Motion for the cross-head is obtained from a bell crank and cam arrangement mounted on the

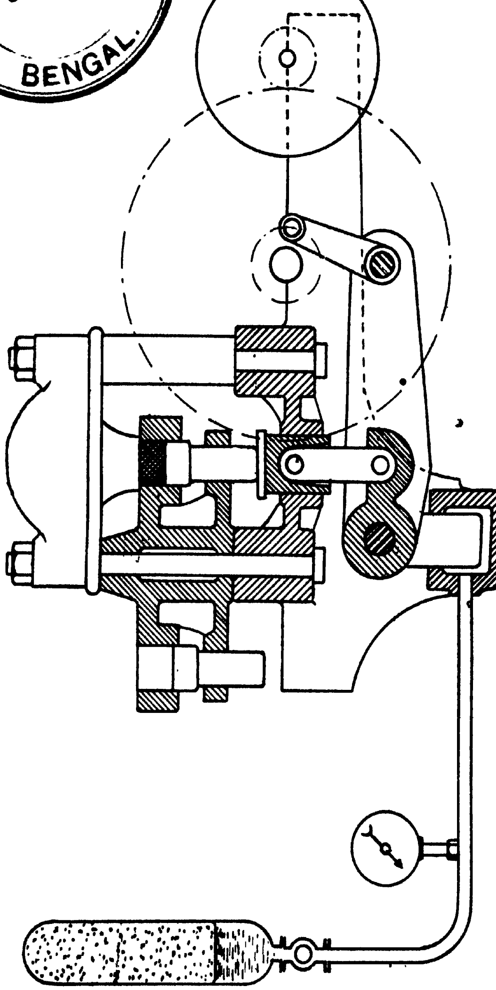

Fig. 15.—Diagram Showing Toggle Action of the Schumacher Press.

main driving gear. A swinging paddle mounted on the feed box sweeps the briquettes onto a conveying belt.

The safeguards against breaking or unduly stressing the principal members of the press are several. In case foreign material, (such as railroad spikes, lump ore, etc.), accidentally enters the mold, the breaking of the machine is obviated by the oil and nitrogen cushion, also by a shearing plate provided in the safety compression block. Shear pins are also provided in the table drive.

A small oil pump provides for the necessary pressure on the nitrogen flask and is used only when changing pressures. A hydraulic gauge records the working pressures up to 10,000 pounds. A nitrogen flask with suitable valves and piping is also provided. About 30 net horsepower is required to operate the press.

Twenty to twenty-five cylindrical briquettes are produced per minute, 7½ inches in diameter and 3 to 3½ inches thick. The hourly capacity will vary from 6 to 10 tons, depending on the specific gravity of the material briquetted.

This type of press is made by Brueck-Kretschel Co., Osnabrueck, Germany, and by the General Briquetting Co., New York.

The White Type of Briquetting Press.—This machine is mounted upon a substantial circular cast iron base frame, to which is fitted a heavy cast iron curb, made in three sections and surmounted by a sheet steel curb. Securely bolted to the center of the base frame is a cone-shape casting, 24 inches outside diameter and 30 inches long, which extends above and below the top of the base frame. This provides a bearing for the main upright shaft, which is of steel. The cross-beam is securely keyed to the main upright shaft. Under the cross-beam and on top of the cone is provided a bronze plate bearing, on which the cross-beam revolves. The cross-beam carries plows, also the offset roller shafts. To the lower end of the upright shaft is fitted a large bevel gear which is driven by gearing mounted in a separate and self-contained gear frame, bolted securely to the side of the base frame. The rollers are fitted with removable bushings and hard white iron tires. The weight of each roller is 6,000 pounds.

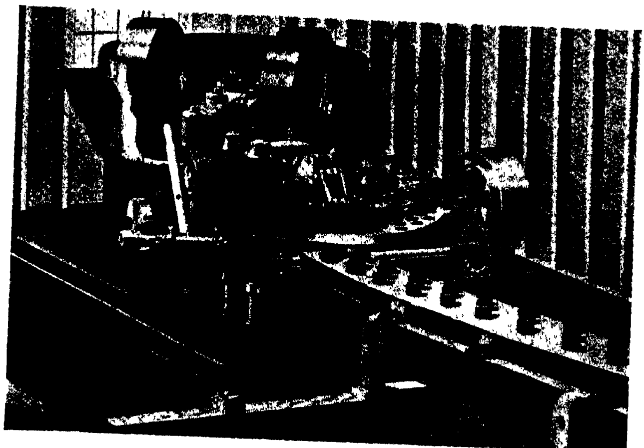

Fig. 16.—The White Mineral Briquetting Press.

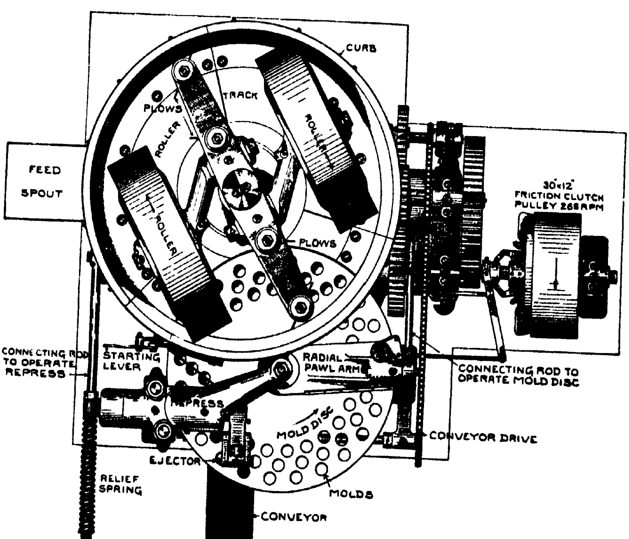

Fig. 17.—The White Mineral Briquetting Press. Diagram of Operation.

The mold disc center is just outside the curb. A segment of the disc is always in the track of the rollers. The disc can be arranged with a series of molds of any desired size. Motion is imparted to the mold disc by the radial pawl arm, journaled at the center of the disc. The outer end of the radial arm is provided with a round steel pawl having a hardened steel toe. As the pawl arm is moved forward by the crank gear and connecting rod, the pawl engages one of the molds and moves the disc. This movement is repeated after each roller leaves the disc. Under the mold disc, in the path of the rollers, is a heavy removable steel wear plate, which forms the bottom of the molds and supports the mold disc while the rollers are passing over it.

The press proper is securely connected to the base frame of the machine, and consists of a heavy upper and lower cast iron frame securely held together by two steel bolts. Extending through the upper press frame horizontally is a steel shaft in which is seated a hardened steel roller and toggle for operating the press plungers. The pressing movement is actuated by a connecting rod provided with a relief spring—this same motion operates the ejector. The connecting rod which operates the mold disc is provided with a convenient adjustment to regulate the movement of the disc so that the repress plungers always enter the molds. The movement of the mold disc is accurately timed so that it is stationary when the repress plungers and ejector enter the molds and the rollers are passing over the disc.

The material is fed into the machine in quantities to provide a bed covering the roller track to a depth of from 2 to 3 inches. The four plows attached to the cross-beam are set at an angle to throw the material directly into the path of the rollers, where it is rolled and plowed up again by the plows following the rollers. The action of the plows and the rotary motion of the rollers, with their twisting and grinding action, thoroughly amalgamate the material and it gradually travels along the circular roller track to the point where a segment of the mold disc meets the roller track.

The plows throw the material into the molds of the disc and the rollers in succession force the material into the molds under pressure. Each briquette is subjected to the pressure of the rollers six consecutive times before leaving the roller track; as

the mold disc revolves this operation is repeated. The briquettes formed in the molds, by the rollers, pass to the powerful repress, where direct pressure is applied. From the repress the briquettes rotate in the mold disc until they meet the ejector plungers, where the briquettes are ejected from the molds and are picked up by conveyor belt. The delivery end of the conveyor belt is equipped with an adjustable arm for automatically loading the finished briquettes into carriers for conveyance to the furnaces, where they are charged as lump ore, or to storage.

This press is made by the Chisholm-Boyd-White Co., Chicago.

The Revolver Press (*English*).—The Revolver press gained its name from the fact that the rotary table was set vertically, and

Fig. 18.—Typical Revolver Press for Fuel and Mineral Briquetting.

turned in a vertical plane, in a manner resembling somewhat the cartridge chamber of the old-fashioned revolver pistol. The type reached its greatest success in Great Britain.

As designed by the English manufacturers the press consists essentially of the vertical table mentioned, in which are set eight molds, with means for feeding the mixture, pressing and ejecting the finished briquettes. The table is rotated between operations through an angle of 45°. The rotation is stopped at the proper interval by a bolt, engaging the slots in turn. The bolt engagement and withdrawal is controlled by a link motion, actuated by a side shaft, which is in turn connected to the main shaft by means of gears.

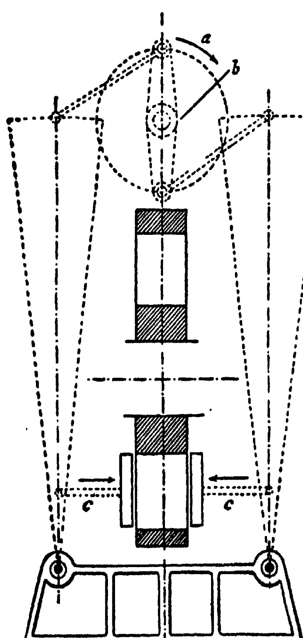

Fig. 19.—Revolver Press—Diagram of Operations.

When the bolt is engaged in the table slot the operations of feeding, pressing and ejection take place at three positions

simultaneously. These three points form a triangle in the upper sector of the revolving table, the pressing machanism being at the top.

The feeding is done by a charging stamp, moving reciprocally in a channel, into which the material is fed from above. The length of stroke of the stamp can be regulated at will, to obtain greater or less preliminary compression. The material, pushed into the table mold by the stamp, is held therein by a fixed abutment at the other side of the table.

The pressing is performed at the top position of the table mold. It is two-sided, being effected by two one-armed levers which are moved reciprocally in opposite directions from the beam simultaneously by parallel connecting rods. The beam rotates in the direction of the arrow, (a) and drives both press stamps (c) into the mold against the mass of previously packed material. After pressing the stamps are withdrawn—as shown in the diagram Fig. 19.

At the ejecting position another piston ram is brought into play, actuated, as is the feed mechanism, by the main shaft through geared connections. This ram pushes the finished briquettes into a channel, along which they are forced to a delivery point, by the freshly formed briquettes. A spring device in the ejecting ram provides for its return out of the mold after it has ejected the briquette.

This press has been used for both fuel and ore briquetting. It is here listed under ore presses because of its adoption by the Coltness Iron Co., Ltd., for the briquetting of Spanish ore smalls.

The manufacturers furnish this press with a double installation of malaxeurs—or fluxers, arranged in series, wherein the material receives steam treatment prior to briquetting. These fluxers consist of cylinders, in which rotate shafts carrying rabbles. Superheated steam is introduced, and the heat, combined with the mechanical action, prepare the material properly. Means for regulating the flow of material between the cylinders is afforded. The feeding mechanism of the press is located at the base of the second cylinder.

In the United States the Revolver press has had extended trials for fuel briquetting. A William Johnson type was pur-

chased by the Bureau of Mines, and under the name of the "English Press" performed during a long series of tests on coals of all sorts brought to the St. Louis and Norfolk stations. A similar press, manufactured by Yeadon was installed by the Arizona Copper Co., and worked with satisfaction until the plant was dismantled. (See Chapter IX). It must be said that the briquette made is too large and bulky for the American market, where the shovelling briquette is in demand.

Among the users of Revolver presses are:

For Coal—Tremsoran Co., South Wales; Patent Fuel Co., Nova Scotia; Lofthouse Colliery, England; Koulebake Mines, Mourorn, Russia; Empresa Industrial Braziliera, Brazil; Lancashire Patent Fuel Co., England, and many others.

For Ore—Etablessements de Poissy, France; Mines de Rio Tinto, Spain; Coltness Iron Co., Scotland; The Carleton Iron Co., England; The Namaqua Copper Co., Namaqualand, and many others.

Revolver presses are made by the English firms, Yeadon Son and Co., and William Johnson & Son, both of Leeds. In Germany the Zeitzereisengiesserei, the Tigler Actiengesellschaft and others turn them out. They are not made on this continent.

The Tigler Press (*German*).—The design is of toggle lever construction without the feature of the revolving table.

The press is illustrated in Fig. 20 and shown diagrammatically in section in Fig. 21.

The mold 19 is located in a stationary mold table 34. On the rear wing of the table 34 is a charging box 35 moved forward by the curved slide 36, and a roller and lever 37. When the charging box advances to fill the mold, it pushes a finished briquette from above the mold to the forward wing of the table 34, whence it falls to the travelling conveyor in front of the press.

The charging box, prior to its advance, receives the proper charge of material from the hopper above, regulated by the charging mechanism—a pair of rotating paddles. When the charging box, carrying its charge, is immediately above the mold 19, the cross-head 16, with the lower stamp, operated through the lever 31, roller 32, and cam 33, is lowered. The mold cham-

bers are thus opened, the contents of th iarging box dis-charged into the mold, and the box returnec its rear position.

The compressing means consists of the cross-heads 13 and 16, at opposite vertical extremities of the mechanism, joined by strong tie rods 15. The crank discs 7, rotated by the drive 5, actuate the toggle lever 10 through two spring-fitted connecting

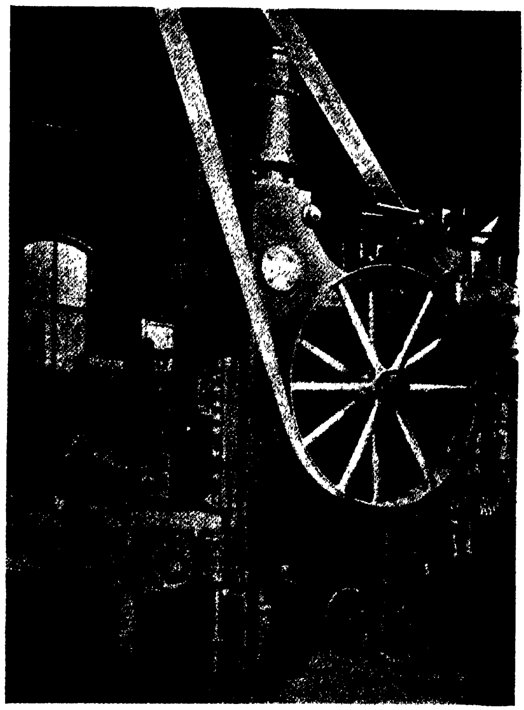

Fig. 20.—The Tigler Press for Fuels and Minerals.

rods 9. The links 11 and 12, connected to the lever 10 by a toggle joint, assume a vertical position, raising the cross-head 13, and, thereby, through the tie rods, the cross-head 16 is raised and effects the lower c mpression through the die 17. Meanwhile the lower link 11 presses down the stamp slides, and the upper stamp 18 is forced into the compression mold.

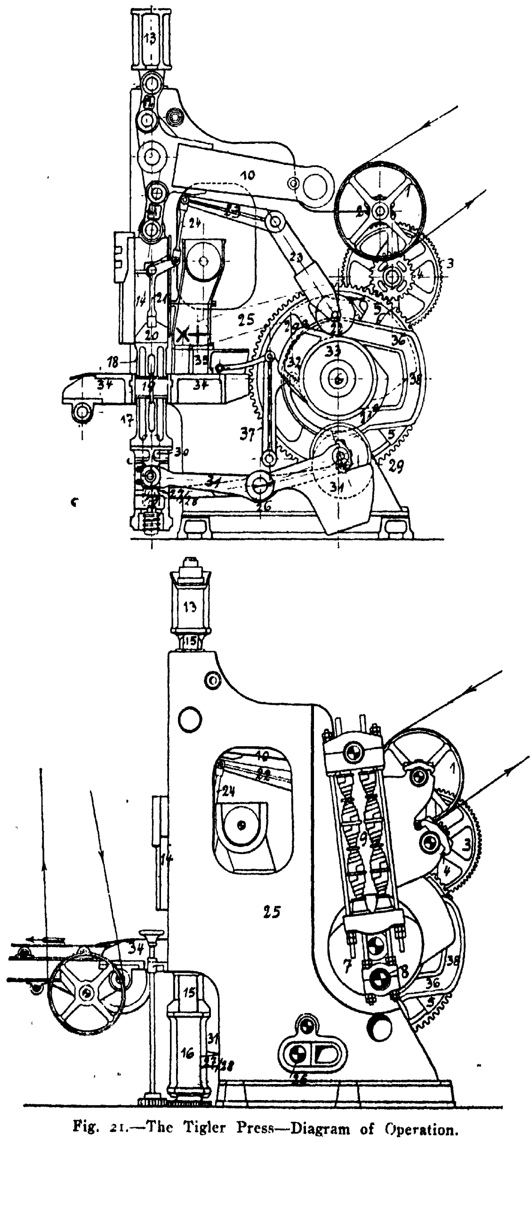

Fig. 21.—The Tigler Press—Diagram of Operation.

After maximum pressure is realized, the intermediate member 21 is thrown out of gear, actuated by tension bar 24, lever 23, roller 22 and cam 21. The die 18 and pressure member 20, are then raised from the mold by the action of supporting rods 30—driven by a double lever 27-28. The upper pressure is thus removed, while the lower die continues to act, the briquette is lifted from the mold, and is ejected by the charging box as previously described.

During working the dies are constantly cooled by water. Excessive pressures are avoided by the insertion of powerful springs on the connecting rods 9. As excess pressure is reached, the springs stretch and breakage is prevented.

The press requires two to three men to operate. There are none now in operation in the United States. The capacities vary from 13 to 18 tons per hour. A smaller size has been put on the market of from 2-5 tons per hour capacity.

A factory making 30 tons per hour of briquettes, equipped with two Tigler presses, is reported as requiring 200 horsepower in all.

The press is made by the Machinen Aktien Gesellschaft Tigler.

Franke (*Handbook of Briquetting*) reports prior to the war sixty of this type at work on bricks and tiles, seven on ore and forty-eight on coal and coke, mostly within the limits of Germany. Among these are:

Matthias Stinner, Mannheim; the Fursteisteiner Gruben-Waldenburg in Silesia; the Elbe Briquette Works at Harberg, and others.

The Sutcliffe Press.—The Sutcliffe press is manufactured by Sutcliffe, Speakman & Co., of Leigh, England, under the trade name of the "Emperor." It makes a large briquette, cylindrical or rectangular, the table molds being shaped in accordance with the service required. This press has been used on all kinds of material—fuel, ores, metallurgical by-products, brick manufacture and metal turnings. During the late war there were several installations at the English munition plants, briquetting metal turnings—with good results, although the pressures are hardly so high and sustained as can be reached on the hydraulic briquette presses.

The press consists of a frame, carrying a shaft on bearings, to which is attached a mold table turned in the horizontal plane. The intermittent rotation of the table is controlled through a ratchet mounted on the table shaft above the table, operated through a crank, rod and pawl—the movement synchronized with the rest of the press operation—so that the table rotation occurs at intervals between the pressing operation.

The frame also holds two cross-heads respectively at the top and near the base of the machine—joined by strong tie rods,

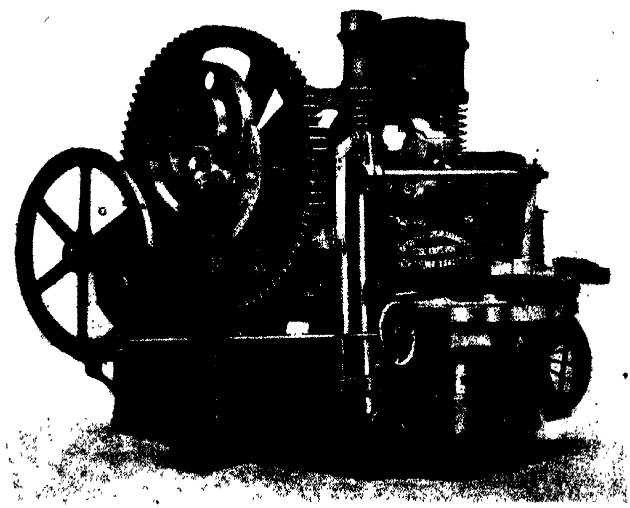

Fig. 22.—The Sutcliffe Press—Used in Metal, Fuel and Mineral Briquetting.

one of which passes through the centre of the table shaft. Between the cross-heads is located the toggle pressing system.

The upper division of the system—*i. e.*, the pressing means located above the table, consists of a press head, carrying a press plate, immediately over the table mold—operating in guides. The press head is raised and lowered—and the pressure transmitted by compression members, connected centrally by a knuckle joint. The knuckle joint moves to and fro, driven by a crank attached to the main shaft. When the knuckle joint is immediately above the mold, the various members of this

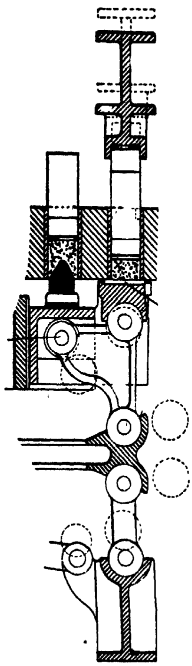

Fig. 23.—The Sutcliffe Press—Diagram of the Packing and Pressing Mechanism.

system are in a line, and pressure is exerted up and down—against the upper cross-head above—and, beneath, to drive the lower compression member, carrying the press plate, against the table mold. As the knuckle joint is moved forward, the members are drawn downward and upward respectively and the pressure is relieved.

The pressure against the upper cross-head causes it to rise (springs are used to control this motion), and the tie rods carry this motion to the cross-head located beneath the tables. Each mold carries its own lower plunger, and the lower plunger of the mold under compression comes in contact with the rising cross-head. Forced into the mold—the plunger pushes the charge against the upper press plate, and in this position the full force of the pressure is exerted upon the material, and the briquette is formed. It is to be noted that the entire force of the compression is taken up by the tension bars between the cross-heads—a tension—thus no great strains are on the framework.

Simultaneously with the exertion of pressure in the high pressure mold, a packing pressure is exerted in the mold preceding. The lower compression member of the toggle system carries an auxiliary plunger above the table in a position just above the mold preceding the pressure mold. This plunger is entirely withdrawn from the table by the action of the toggle joint when pressure is removed, but is made to serve as a packing means while the toggle is in pressure position—being forced down upon the material in the preceding mold. The pressure plunger is not concerned with packing, the material in this operation being simply forced down upon it.

Feeding is done at a point diametrically opposite to the pressure point. A cylindrical pan receives the mix. A number of

stirrers keep the material in motion, filling the mold. The quantity of material fed to the molds is regulated by means of a gate controlled by a hand wheel.

The molds are lined, and are easily relined after wear. The linings can be turned, giving two wearing faces.

The briquettes are ejected from the mold immediately after the pressing position. A plunger, located beneath the table, pushes against the mold plunger, causing the briquette to rise to the table level, whence it is removed by an attendant, or mechanically thrown on a belt, according to the value of the brick and the necessity for preserving it from chipping at the corners. The cam, driving and turning the ejecting mechanism, is located on the main shaft.

The advantages claimed for this type of press are:

(a) It can be made to give a top and bottom equal and simultaneous pressure, or to give a bottom pressure only, or again, it can be arranged to give a quadruple pressure, the final pressure being greater than the first.

(b) All its principal working parts are above the level of the table, thus preventing wear otherwise caused by sand and dirt falling into the bearings.

For fuel briquetting, with pitch or oil binders, a vertical fluxer is attached to the feeding pan.

The capacity is 1,000-1,500 briquettes per hour—5 to 15 tons per hour depending upon density of material and speed of operation. The weight is 13-14 tons.

Some of the installations of this press are:

The Coltness Iron Co., Ltd.,—briquetting fine brown hemtite.

The Helsingborgs Kopparverks Aktiebolag—briquetting pyritic cinder.

The Alquife Mines & Railway Co.,—briquetting brown hematite.

The Langloan Iron & Chemical Co., Ltd., and others.

2. Mechanical Presses Primarily Designed for Fuel Briquetting.

The Couffinhal Press.—In the briquetting of coal fines in Central Europe—not including the braunkohle industry—the Couf-

finhal press is, by far, the most prevalent. The patents upon the design have long since run out, and it is at present manufactured by the firm of Schuchtermann & Kremer, of Dortmund, Maschinenfabrik in Herne and the firm of Maschinen-bauanstalt Humboldt in Kalk, as well as others. There has been but one delivery of the press in the United States, and it is unlikely that any great progress will be made on account of the size and shape briquette made. The design, in other words, is not adaptable to the pro-

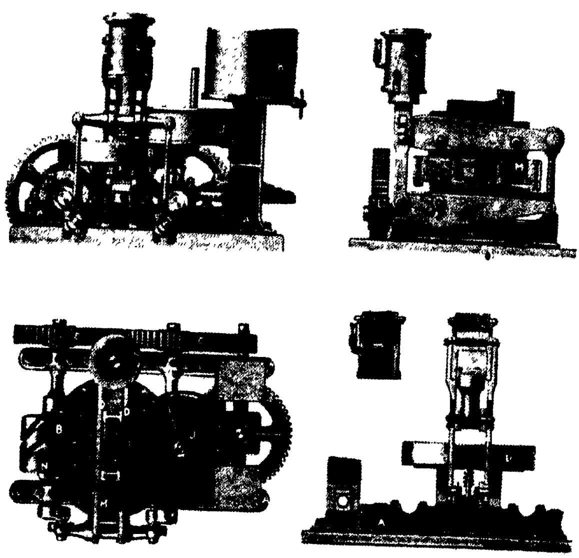

Fig. 24.—The Couffinhal Press—In Plan and Section.

duction of the shoveling briquette demanded by the American market. For the market it covers, however, the Couffinhal press and the Couffinhal briquette produced by it, leave little to be desired. The briquettes are usually turned out in flat lozenge shape, weighing nearly seven pounds.

Referring to the figure, the press consists of a cast iron frame A, a vertical shaft carrying a mold table B, rotated in a horizontal plane between double pairs of swinging beams D-D, located respectively above and below the table. During rotation the table

passes over a fixed foundation plate, which forms the bottom of the molds, except during pressing operation.

The swinging beams D-D carry the pressing mechanism. Their fixed fulcrum lies in the base A at one extremity of the lower beam. Each beam carries a press stamp H-H, operating in the molds C, and at a point diametrically opposite to the position of the stamps H-H, an ejecting die M enters the molds to discharge the finished briquettes. The intermittent turning of the table is controlled by the driving roll N, which engages lugs, carrying them forward in the periods between pressing operations and releasing them as the mold comes under the dies. The operation of the stamps through the beams D-D is actuated by the disc cranks F-F, directly connected to the drive E, and connected by link bars G-G to the swinging beams.

At a point midway between the pressing and ejecting devices over the mold table is located the feeding device consisting of a hopper J into which is discharged from the malaxeur K the briquetting mixture. Within the hopper J a pair of rotating arms distribute the mixture, filling the molds evenly and properly.

In the operation of the press the feed is made as described, and, simultaneously with the feed, the pressing and ejecting operations occur at their respective points. The turning of the crank discs F-F through the links G-G serve to bring down the upper swinging beam D, and the upper press stamp H enters the mold, pressing the mixture now resting on the lower stamp. When the limit of upper compression has been reached, the crosshead at the front of the upper beam rises, carrying with it the hydraulic cylinder and the tension bars I connecting with the lower swinging beam. The lower press stamp, connected to the lower swinging beam, comes into play, bringing pressure from below to the same degree as the briquette was pressed from above.

On further rotation of the crank disc the entire system returns to its former position and compression is released. The upper stamp emerges from the mold and the lower stamp is forced, by spring action, to the bottom of the mold. Here the turning mechanism comes into play and a new charge is brought between the stamps.

At the ejection point an ejecting plunger is fastened to the upper swinging beam. During the revolution of the table it is elevated, but during the pressing period it plunges into the mold below and discharges the finished briquette downwards. This action completed, the stamp is withdrawn for the next operation of the table. The falling briquette is caught on a flap above the lower swinging beam connecting with an inclined chute, whence the briquette is carried to its delivery point.

These presses carry a hydraulic safety device L to prevent over-pressing and breakage. It consists of a cast iron cylinder divided into two spaces: upper and lower. Into the lower space a pressure piston, rigidly attached to the upper beam, enters from below. Above the pressure piston, the lower space is filled with water. Between the upper and lower space disc valves are inserted, to which are fastened vertical bars passing through the cover of the upper space. Springs are wound around these bars. When the piston is driven into the cylinder, the suction valve remains closed, and the pressure valve as well, until the pressure of the water above the piston reaches a predetermined point. At this point the pressure valve lifts and the water is admitted above until the hydraulic pressure falls and the tension of the pressure valve spring comes into play. At this point the pressure valve closes again. As the piston recedes, the pressure valve remains closed, while the suction valve opens and the water returns to the lower section.

The firm of Schuchtermann and Kremer make this press in four sizes. For the 2-ton per hour press, 6 to 8 horsepower is required; for the 6 tons per hour press, 16 to 18 horsepower; for the 10-12 tons, 25 to 30 horsepower; for the 18-20 tons, 50-55 horsepower. It is stated that the Couffinhal press has been built for briquettes as small as 2 pounds, but is hardly recommended for the purpose. While the press has been used, primarily, for coal briquetting, some installations have successfully handled mineral fines.

The Meguin Type.—This toggle press has recently attained considerable vogue in Germany, especially at gas plants, where it has appealed because of its simplicity and cheapness, for the briquetting of coke braize. The press was especially popular

during the war, when fuel was dear and scarce. As seen from the illustration, the press operation is preceded by a vertical fluxer similar to those used on the Couffinhal and like systems. The pressing mechanism consists of a table rotating in a horizontal plane, the control—*i. e.*, the movement and stoppage thereof—

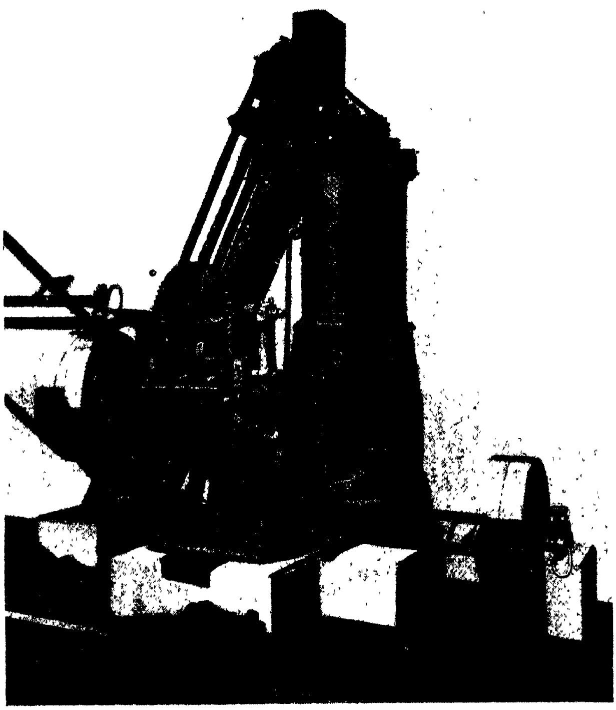

Fig. 25.—The Meguin Press—Designed Especially for the Briquetting of Gas Coke Braize.

operated by a bracket and blocking device. Pressure is from above only. There are four piston plungers set in a die operating downwards driven through a toggle arm. Between each piston head and the die holder is a spring. Beneath the table is a stationary die plate. The table molds are arranged concentrically in pairs. The molds are filled by a special feeding mech-

anism, the material being dropped into the hopper from the fluxer—that material being a well-fluxed mixture of pitch and coke braize ground together in a hammer mill or similar apparatus prior to fluxing. From the feed the molds are carried by the table movement to the pressing position, where the four dies descend upon the material in the molds. Thus four briquettes are formed simultaneously. They are ejected by thrust members at the front of the press. The briquettes pass to a shaking screen where they are freed from dust and delivered to belt or cars. The press has a capacity of one-half to one ton per hour.

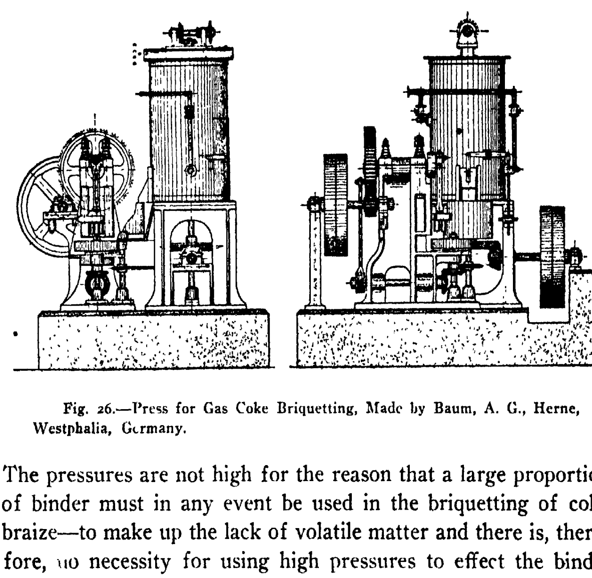

Fig. 26.—Press for Gas Coke Briquetting, Made by Baum, A. G., Herne, Westphalia, Germany.

The pressures are not high for the reason that a large proportion of binder must in any event be used in the briquetting of coke braize—to make up the lack of volatile matter and there is, therefore, no necessity for using high pressures to effect the binder economy. This press is made by Meguin, A. G., Dillingen, Germany, and is a comparatively recent design. A similar design also illustrated herewith is made by the Baum Works, Herne, Westphalia.

The Exter Press.—The open-mold type of press, especially identified with the German "braunkohle" briquetting industry, has been designated by Professor Franke as the Exter. The principle of briquetting in the open mold is not new, and this type of press has

been in use over sixty years, so that it is to-day a well developed apparatus—well adapted to certain specific uses. Notable firms in Germany making this press are the Zeitz Eisengiesserei and the Maschinenfabrik Buckau A. G., of Magdeburg. In the United States the Fernholtz Machinery Company have designed an improved type, and are manufacturing it for the American market.

Fig. 27.—Battery of Exter Presses Installed at the Wilhelmina "Braunkohle" Mine near Cologne, Germany. Installed by the Maschinen Fabrik Buckau, Magdeburg, Germany.

In general these machines are designed to briquette lignite, peat, and wood chips, that will cohere under pressure and frictional heat, releasing and bringing into play their own resinous or bituminous matter. While the press could probably be used to briquette material containing binder, other presses cheaper in operation perform this requirement equally well, at less expenditure for power, and less risk of breakage.

This press is of the horizontal plunger type, the characteristic feature being the open mold. The travel of the plunger is relatively short, but it is massive and heavy and is driven with tremendous force, stored in an enormous fly wheel.

The characteristic feature of this press is the mold—open at both ends, but with the opening at the delivery end smaller than the one in the receiving end. In the sketch (Fig. 28) this method of operation is illustrated. The mold narrows between a and b. The plunger E moves forward to the position D, forming the material received at C into a briquette. The line of briquettes previously formed, lying all along the mold from D to F furnish a back for the formation of the new briquette. This whole line is shoved forward by the operation of the plunger at D, and the last briquette in the line is discharged at F.

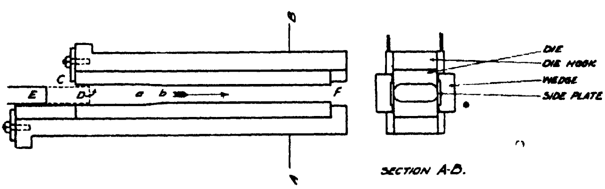

Fig. 28.—The Exter Type of Press. Diagrammatic Representation of the Principle of the Die Angle.

At a-b the mold constricts, and the briquettes are therefore forced through an opening of smaller cross-section. Such constriction develops enormous pressure—up to 24,000 pounds per square inch—and the presses are therefore built along very rugged lines, and require 100 horsepower, working at one hundred strokes per minute to deliver 6,000 briquettes, or 3 tons per hour. The briquettes ordinarily weigh 1 pound each. A large part of the energy of the press is converted by friction into heat, and the heat thereby evolved serves to soften the bitumen of the lignite, which thereby forms the binding medium. The hot "rope" or column of briquettes is forced by the continuous motion of the plunger, fabricating new briquettes, along a long channel, set up in the yard of the factory, where cooling takes place.

The press is directly connected to a steam engine. The stamp is bolted to a head-block, driven by connecting rod and eccentric.

The amount of constriction between a and b is usually expressed as an angle of which the difference between the two vertical heights divided by the length of the constricting portion

of the mold is the tangent. This angle is called the die angle. The standard angle used is 4° 20′. The length of constricted area in the German lignite machines is 3.1 inches and the decrease in vertical height a little less than one-quarter of an inch.

The Fernholtz design of Exter press, as used by the Johnson Company, of Scranton, N. D., consists of a base composed of two sections, right and left, bolted together. In the upper end of the base is a recess for the mold. Over the mold is a cap, holding the mold in the recess, and bolted to the frame.

The feed box of the mold comprises a U-shaped member, holding a hopper. The hopper is an inverted cone of sheet iron. At the base of the U-shaped member is a semi-cylindrical space in line with the mold and just in front of it. Into this space the hopper discharges its material. The plunger forces this material into the mold, where the operation proceeds along the principles of the German Exter Press.

This design has a cooling feature. In the mold are air ports, large in diameter on the outer shell, but decreasing toward the inlet end. They extend rearward with respect to the direction of the movement of material, which construction enables the briquetted material to keep clear the inlet. The mold designed by Mr. Fernholtz has the merit not only of providing cooling ducts and allowing gases to escape, as above mentioned, but has a satisfactory removable internal wearing surface—that can be replaced as it becomes worn. The lining consists of four pieces, making straight flat cheeks at the sides, with top and bottom of trough-shaped perforated shoes of raw steel, swaged to form and planished.

The lining can be renewed as needed. The German presses are usually made without cooling inlets or mold lining.

The Fernholtz Company is the only manufacturer in the United States making open-mold briquette presses, and these have so far been confined to lignite operation. In Europe, an open-mold type of press, known as the Bouriez, has been used on coals mixed with binder. While good results have been obtained, so far as tonnage is concerned, the briquettes have not been equal to those produced on the closed-mold types. This press is provided with hydraulic balance to insure an equable pressure,

with diminished strain. The "rope" of briquettes formed is cut into blocks by strings or knives of the discharge end.

An important adaptation of the open-mold press is the Arnold—made by Ganz & Co., of Ratibor, Upper Silesia. This press, in conjunction with the Arnold system of preparation (Chapter VII) is the only successful device now operating in the field of wood chip and sawdust briquetting. The pressures and frictional heat are controlled to a nicety in the apparatus to obtain binding action without charring or damaging the wood fragments. (See Chapter VI).

The Fernholtz Press.—This press was designed by Emil Fernholtz, of the Fernholtz Machinery Company, of Los Angeles, California. It has found its especial application in the briquetting of "carbon black"—a carbonaceous oily residue of the California gas plants—where illuminating gas is manufactured from petroleum—(a description of this type of plant is found in Chapter XI).

It has not been Mr. Fernholtz's idea to confine this press to carbon black briquetting. It is designed for fuel briquette fabrication, wherever binder is required as an admixture to the fuels. In the case of "carbon black," the residual oil therein contained is, in effect, an extraneous binding material. The Fernholtz Company has not advanced this press for the briquetting of lignites.

The press in question consists of a frame, consisting of three cast iron members; *i. e.*, the bed plate, the intermediate and the top being joined severally by standards at the sides. In the intermediate member are mounted the molds—together with charging table (rear) and discharge table (front) Fig. 30. There can be as many rows of molds as desired. The molds themselves are stationary—*i. e.*, the revolving table principle is not used.

The material is fed into a hopper on to the charging table, and—the mold plungers being lifted—is shoved by a pusher into the mold area, each mold filling as the material passes over it. The amount of material the pusher "bites off" each time is automatically regulated so that just sufficient to fill the molds is provided.

There are plungers at each end of each mold, operating in opposite directions to form the briquette—the bottom plunger forms the base of the mold during charging. The plungers are

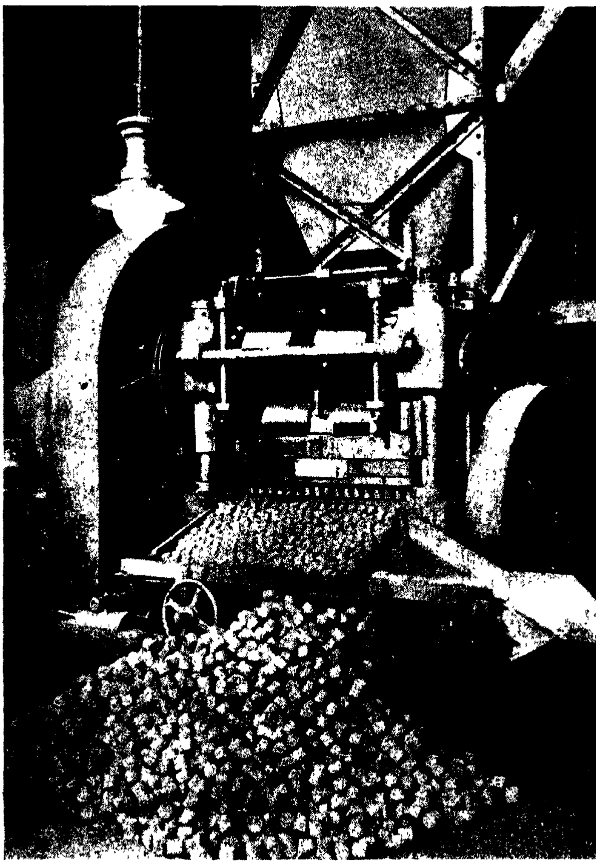

Fig. 29.—The Fernholtz Press—Making Briquettes of Oil-Gas Carbon.

nested in large iron members—above and below—known as ram holders. The nests of rams, therefore, operate as units. The top ram holder and the bearing roller above it are purposely made

massive and heavy—sufficient to give a pressure—through their weight—equal to one-fourth the maximum pressure to which the briquette is subjected.

Above and below the mold holders are bearing rollers, mounted on shafts—the corresponding faces of the mold holders being turned to receive them, and permit their revolution. Above and below the bearing rollers are cams, so designed as to shape and timing as to bring the pressure to bear with proper increase and decrease.

The cam arrangement is shown in Fig. 30. The illustration shows the mechanism at the point of greatest top pressure.

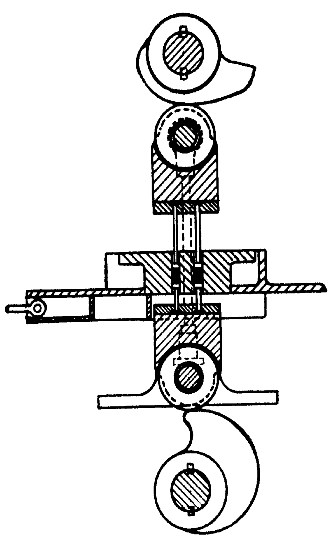

Fig. 30.--The Fernholtz Press—Cam and Pressure System.

The cams are arranged and timed to give the following result:

After the molds are filled, the charger is withdrawn. The upper cam turns and rotates the upper bearing roller, which descends, carrying with it the upper ram holder. The rams enter the molds, forcing the material against the lower plungers, still at rest, serving as stationary mold bottoms. The pressure increases up to the point shown in the diagram, at which point the upper cam passer the low point of contact, and upper pressure is withdrawn, except for the weight of the upper ram holder and bearing, amounting to one-fourth the pressure, as aforesaid.

The lower cam now begins to press, in its rotation, against the lower bearing roller, raising it, together with the lower ram holder. The briquettes, still under pressure, are carried through and out of the mold, the upper roller and upper ram holder being carried upward as well. When the briquettes are clear of the mold, an auxiliary cam, operating on the same shaft as the

upper pressure cam, comes into play, lifting the upper ram holder clear of the briquettes. The charger, properly synchronized, moves forward at this juncture, sweeping the newly formed briquettes on the discharge table.

These presses are made in capacities from 25-75 tons per day.

The important feature of the press embodies the principle discovered by Mr. Fernholtz; namely, discharge of the briquette from the mold under diminished pressure. The discharge under relaxed pressure corrects the tendency of the briquettes to laminate, check and crack.

This type of press has been installed in the following gas plants:

San Diego Cons. Gas & Electric Co., San Diego, Cal.
Los Angeles Gas & Electric Co., Los Angeles, Cal.
Southern California Gas & Electric Co., Los Angeles, Cal.
Pacific Gas & Electric Co., San Francisco, Cal.
Pacific Gas & Electric Co., Oakland, Cal.
Portland Gas & Electric Co., Portland, Oregon.

The Renfrow Press.—The Renfrow briquetting press was very largely the design of Mr. E. D. Mizner, who acted as superintendent of the Renfrow Briquette Machine Co. Originally, two machines were built: one having been installed by the Western Coalette Fuel Company at Kansas City, Mo., and the other was delivered to the Bureau of Mines, being used by them at the Fuel Testing Plants at St. Louis in 1904 and at the Jamestown Exposition later. The machine delivered a maximum pressure of 2,500 pounds per square inch as finally designed, although the original was capable of but 1,000 pounds per square inch. The last installation was made by the Detroit Coalette Co.

The machine included steam-jacketted cylinders horizontally placed P-P-P (Fig. 32), which performed the function of the vertical malaxeur usually found in briquetting plants; that is, they performed the final mixing of the fuel and binder and contributed to the liquidity of the binder. From these mixers worm conveyors Q carried the material through the cylinders. The material was thence delivered to a hopper T and carried down to a die filler U. In the operation of the press pulverized fuel was

used, according to the English system, being mixed with the coal in a Williams mill, which reduced the mixture to small pieces and dust. Thus a very satisfactory degree of preliminary mixing was obtained before the material passed into the three steam mixing cylinders P-P-P. Plungers forced the mixture into the die filler U, which filled the dies or molds with the proper charges. The

Fig. 31.—The Renfrow Press for Fuel Briquetting.

briquettes were formed in the molds by plungers, twelve on each side of the die holder. The plungers operated at eighteen strokes per minute. The action of the plungers and, in general, the synchronism of the apparatus was arranged through a system of well-designed cams. On the return stroke of the plunger

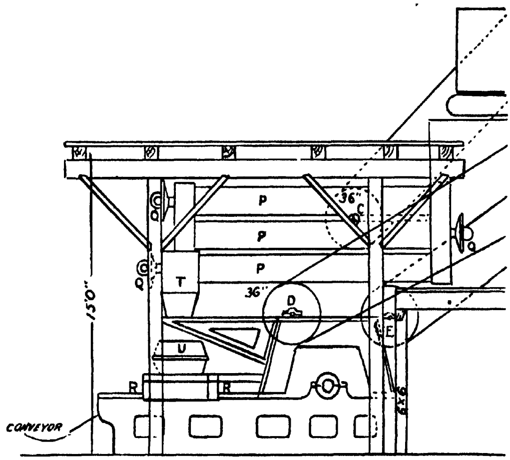

Fig. 32.—The Renfrow Press—Diagram of Operation.

the briquettes were discharged from the molds and dropped on a conveyor, which brought them to the front of the machine and dumped them on a cross conveyor going to the storage bin. It will be noted that this machine is not of the rotating table type, the briquettes being pushed from the molds as made, the molds themselves being in stationary position. The capacity of the press is about 71 tons per ten-hour day. The horsepower required is 50.

The Rutledge Press.—This press consists of a chain of molds or die plates, passing under a feeding hopper and between two revolving drums, which carry punch rams. In each die plate are fourteen dies. Twelve punch rams are mounted on each lower drum; each punch ram carries fourteen punches. On each punch ram two pilot punches engage the die plates prior to the entrance of the punches into the dies; these pilot punches not only serve to move the dies forward, and to align the dies and punches. The lower punches entering the dies again at the lowest point of their travel eject the briquettes.

The punch rams oscillate on seats fixed in the drums, the movement is produced by arms on the rams, traveling in fixed cam tracks. This operation is timed with relation to the angular displacement of the punch rams about the main shafts, so that the punches compress the briquettes on a straight line with a positive downward pressure.

The bearings of the upper drum are set in vertical guides, and work against helical springs. These springs move upward when the pressure on the briquettes exceeds 4,000 pounds per square inch. The briquettes are cylindrical in shape, with hemi-spherical ends, and weigh 10-16 ounces. The press makes 32 to 33 tons of briquettes per hour.

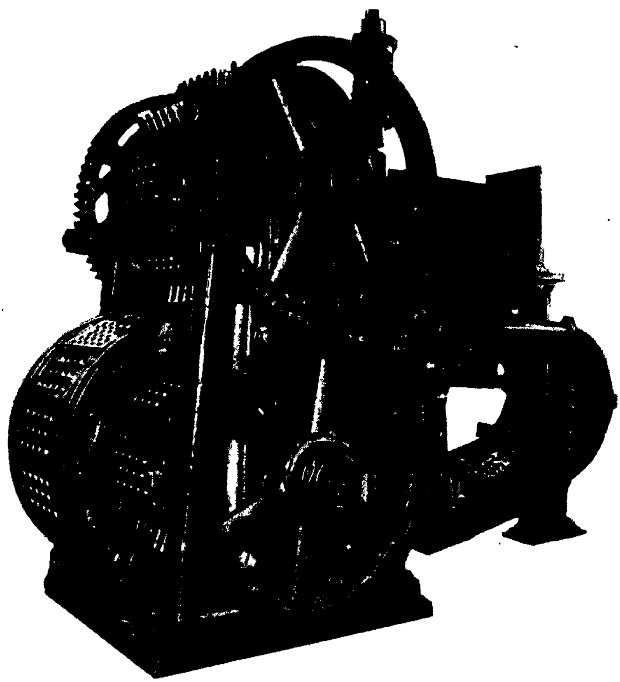

Fig. 33.—The Rutledge Fuel Briquetting Press.

The Rutledge press is built entirely of steel, with the exception of the bearings, which are of bronze alloy. The parts receiving the most wear, such as the die bushings, cam track, and punch ram guide rollers, are of chrome-nickel steel, heat treated, or manganese steel, and are easily replaceable.

The briquettes are discharged from the press to a perforated chute which delivers them to the cooling conveyor. All

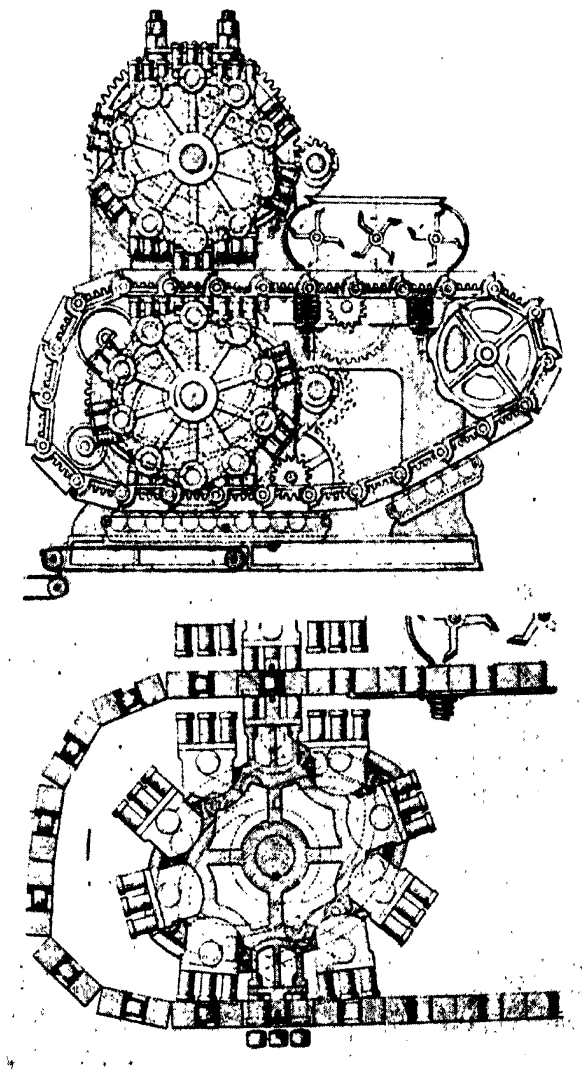

Fig. 34.—The Rutledge Fuel Briquetting Press. Diagram of Operations.

of the fines from the press and any damaged or inferior briquettes pass through this chute into a flight conveyor. This conveyor passes underneath the press and delivers its charge into the elevator which returns it to the fluxer.

This press has been installed by the Malcolmson Briquette Engineering Co., at the plants of the Standard Briquette Co., Kansas City, Mo.; the Pacific Coast Fuel Co., Seattle, Wash.; the Berwind Fuel Co., Superior, Wis., and the plant of the Pocohontas Fuel Co., at Norfolk, Va.

The Schorr Briquetting Press.—In this press two sole plates carry a stationary steel shaft, upon which a large spur wheel revolves, driven by means of gearing, countershaft and friction-clutch pulley. The spur wheel rim is integral with a mold ring

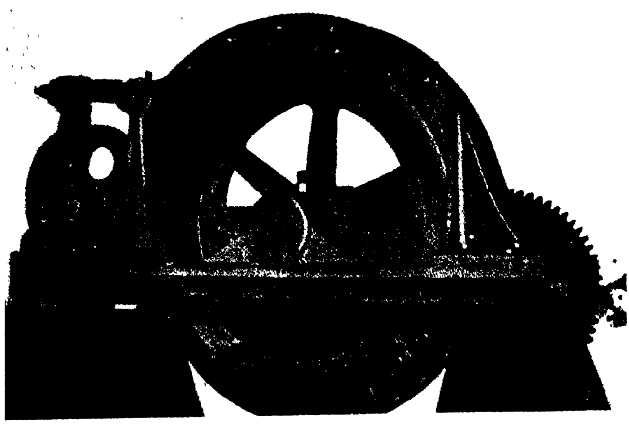

Fig. 35.—The Schorr Fuel Briquetting Press.

which has a series of orifices carrying sliding plungers. The plungers are controlled by cams supported by shields. The pistons are gradually withdrawn, and in passing the feed-box the molds are filled with the briquetting mixture. At the end of the feed-box surplus material is scraped off by a steel plate. After passing the scraper plate the pistons are forced in, pressing the material against the resistance block. When the pistons are about one-half inch from their terminal, they strike against

a rocking pressing-wheel and are forced home. In this way the briquettes are made, and the maximum pressure attained. The plungers are released from the camway after final pressure is applied. The rocking wheel is pressed against the plunger-heads by means of an adjustable spring, which permits regulation of pressure up to 4,000 pounds per square inch. After leaving the pressure-wheel, the plungers are gradually forced forward to eject the briquettes, which drop upon a vibrating discharge-chute.

The machine is entirely self-contained. There is no possibility of overfeed or obstruction. It is also claimed that as the pressure is applied slowly and gradually, this type of press permits briquetting mixtures containing from 13 to 14 per cent of moisture, and that this is an advantage not possessed by intermittently-acting presses. Up to 1908 two designs have been made, one with two rows of 2-inch cylindrical molds, and the other with two rows of 2.5- by 2.75-inch rectangular shapes with rounded corners. Other shapes and heavier briquettes are possible. The press can be built for a much larger capacity.

From 80 to 120 briquettes are made for each revolution, the number depending on the size and shape of the briquettes, which govern also the capacity, which varies from 6 to 24.5 tons per hour.

The single installation of this press was made at the Western Fuel Co. plant at Oakland, Cal.

The Ladley Briquetting Press.—Another rotary plunger type of press is the Ladley, which operated for several months at the plant of the Indianapolis Pressed Fuel Company, Indianapolis, Ind., about 1913. The plant was subsequently destroyed by fire and never rebuilt. The press was used in connection with the lignite experiments of the Bureau of Mines and the report upon its work was favorable.

The press consisted of two rows of molds, fifty-four molds in each row, arranged in the heavy rim of a wheel. Opposed to the molds is a series of one hundred and eight rams, one to each mold. The molds are filled by a special device, operating in a hopper, consisting of paddles mounted upon rotating shafts. Upon the filling of the molds by this device, the turning of the wheel brings the molds under a series of three tamping wheels, which tamp the material in the molds by means of a rolling pressure.

After the tamping operation is completed, the further rotation of the wheel brings the series of molds under anvil blocks mounted on a belt, which, travelling with the molds, close their outer ends and permit the application of the ram pressure from the inside. The tangential travel of this belt amounts to nearly a quadrant of the revolution. The rams, as usual in such designs, are operated by cams and so designed as to plunge the rams against the material as soon as the anvil block has closed the

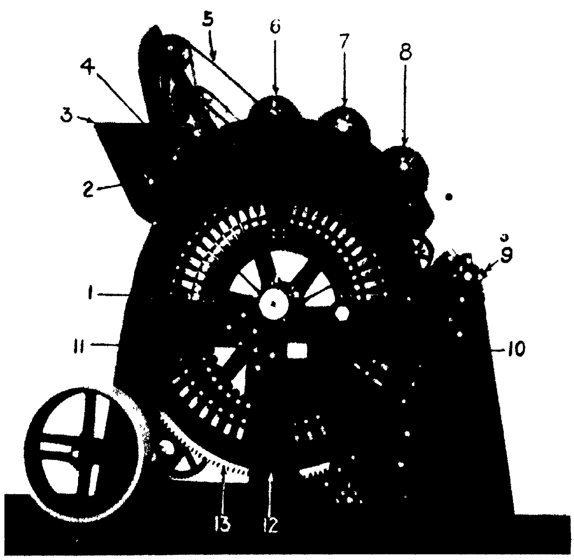

Fig. 36.—The Ladley Fuel Briquetting Press.

mold. At the lowermost point of the wheel, the anvil block belt turns, taking the anvil blocks out of the mold and sending them back, on their return travel, to the high point, where they re-enter the molds in succession as before. The block being removed, the plunger, at this time pressing downward, ejects the briquette from the mold. In dropping, the briquette is picked up by a traveling belt.. The drive is maintained by pulley and gear in the usual way.

ROLL-TYPE PRESSES.

1—Vertical Feed.

Few of the foregoing (piston- and mold-type), have proven adaptable to coal briquetting in the United States; although their use is widespread in Europe. The Europeans are accustomed to big briquettes. They like them for their close packing, and consequent economy in transport. The Americans insist

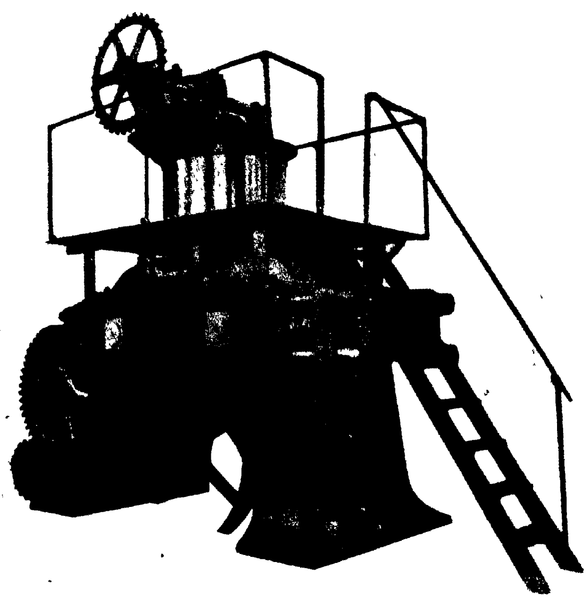

Fig. 37.—Belgian Briquetting Press—Vulcan or De Villiers Type.

upon a "shoveling" fuel. American briquettes range from 1½ to 8 ounces in weight, with few exceptions. Costs of making such briquettes on piston- and mold-type presses are prohibitive.

Roll-type presses work on the principle of the horizontal rolls used for intermediate crushing in ore dressing plants. Two rolls, not quite touching, rotate at equal speeds, and in opposite directions to each other. In each roll is a series of half molds, corresponding with equi-dimensioned half molds in the other.

The material, fed from above to the point of approximate contact of the rolls, is squeezed in the molds, and as the half molds separate beyond the point of approximate contact, the briquettes drop to a screen or chute situated beneath the press. All roll-type presses using vertical feed operate in this wise.

The Belgian Type Press.—This is the original type of roll press.

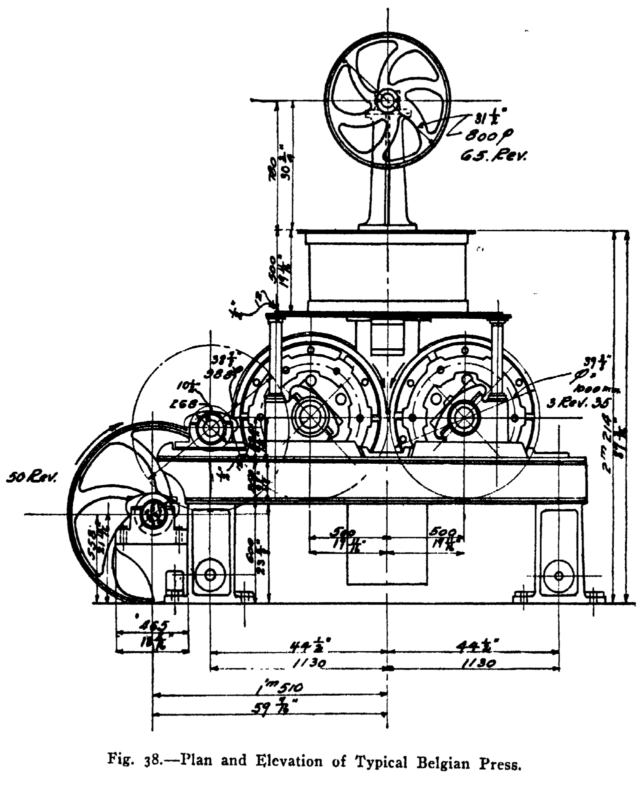

Fig. 38.—Plan and Elevation of Typical Belgian Press.

The design is not new, and they are made by several manufacturers. The original designs called for egg- or ball-shaped briquettes, largely because these shapes show least degradation in tumbling barrel tests. Indeed for this reason this shape is pre-

ferred to-day by many, although the growth in favor of the pillow-shaped briquette is marked, due to lessened wastage by fines production in the course of pressing.

In the typical Belgian press the molds are cut semi-egg-shaped in a steel tire, which is shrunk on a spider, the latter being mounted on the roll shaft.

Each roll is in two parts, made up of two equal-sized rolls, separated by the gear wheel, which is in the centre of the machine. These gear wheels are so placed to ensure balance and equal distribution of strains; as well as absolute accuracy of contact between the molds. The drive is usually by pulley, operated from a line shaft. The sequence is: pulley to a spur wheel, spur wheel to large gear on another shaft, spur wheels on this shaft to large gears on the end one of the roll shafts, gear wheel in centre of this roll shaft to gear wheel in the centre of the other roll shaft.

Even distribution of the feed is of prime importance. Over the rolls is mounted a hopper, containing a vertical shaft—driven by a chain drive. On the shaft are attached stirring fingers, which push the material (fed in from above) over the floor of the hopper discharging it continuously through radial openings in that floor. On each side of the rolls are cheek plates, usually of bronze, which keep the material from falling off at the side.

When the egg molds are used there is a considerable waste space between them. Material is caught between these waste spaces and is pressed, falling through with the briquettes as "fins" or apart from them as dust. The percentage of such fines production is high, and its presence necessitates a shaking screen at the base of the press. The fines as produced are sent back to the press hopper for repressing.

When the pillow shape is used on the press, the production of fines is much smaller.

Safety of operation is frequently obtained by the use of springs, whereby the accidental intrusion of hard material between the roll faces, forces the rolls apart, against springs which are stiff enough to hold the rolls at their proper clearance under ordinary conditions. Some manufacturers prefer the rigid design,

holding that springs in time give under ordinary conditions, and the rolls are kept too far apart, resulting in poor briquettes, insufficiently pressed.

Belgian eggette or ovoid presses are made by many manufacturers:—In England Yeadon Son & Co., Wm. Johnson & Co. and others have sold a large number. In Germany, though the vogue of eggette briquettes has made little progress as a home fuel, the firms of Zimmerman & Haurez, Schuchtermann and Kremer, Baum, Humboldt, and others are making them. In this country the Vulcan Iron Works makes an eggette press—an improved DeVilliers pattern, and the Traylor Iron Works have developed an improved Belgian press as well. The latter is now in use at the anthracite briquetting plant of the Lehigh Coal and Navigation Co., Lansford, Pa.

The Zwoyer "Universal" Press.—The "Universal" press, invented by Mr. E. B. A. Zwoyer and redesigned by Thomas Gilmore, Jr., is the result of a comprehensive study of all types of roll or tangential presses and extended experience in operating briquette plants.

The press is exceedingly rugged and has the advantages therefrom of very little repair cost and smooth and even running. It is simple, having the fewest moving parts consistent with performance. The feed is especially noteworthy. It consists of a vertical hopper only, mounted directly above a pair of briquetting rolls. In the vertical hopper a column of material is fed, and the size and weight of the column determine the actual weight upon the briquettes. The weight of the material presses down upon the mixture actually undergoing pressure. The pressure of the material thus thrown against the rolls produces a reaction, which is exerted by the rolls themselves as pressure upon the forming briquette.

The press proper consists of a frame—(a single casting comprising the base and two double-walled side girders)—rolls, drive and feed. The side girders of the frame contain recesses for the bearings for the driving shaft and for the two intermediate shafts. Two heavy steel tie bars surmounting each of these girders take up the thrust of the rolls through the bearings.

The rolls are made of a special grade of iron and the pockets are cast in without machining, which conditions insure hard wear-

ing surface and long life. The rolls are made in one piece and are keyed directly to the shaft without a spider. In designing the diameter of the roll maintains a definite relation to the size

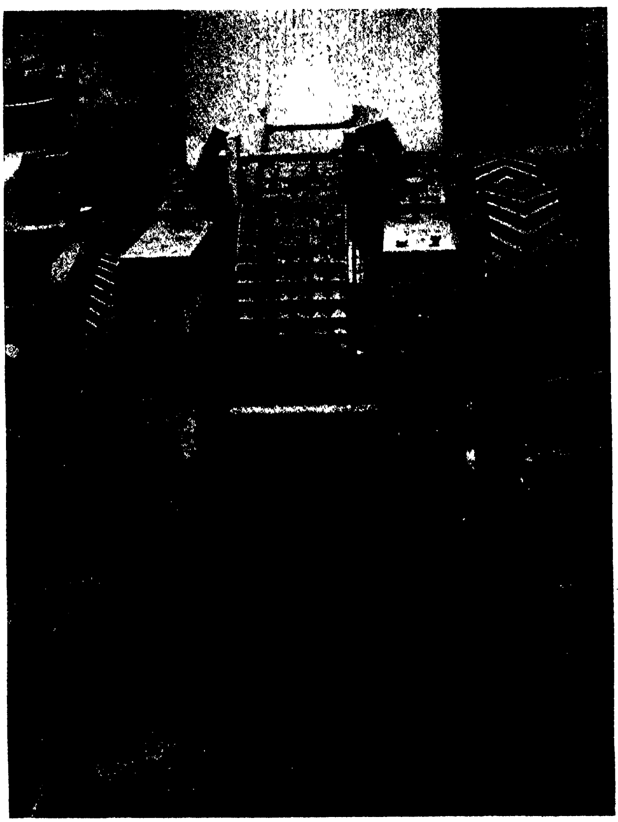

Fig. 39.—The Zwoyer Universal Press.

of the briquette made. For a 2-inch square briquette, weighing 2 ounces, or somewhat less in the case of fuels, 20-inch diameter rolls are used

A machine with a roll speed of twenty-two revolutions per minute has a capacity of 15 tons per hour, when making bri-

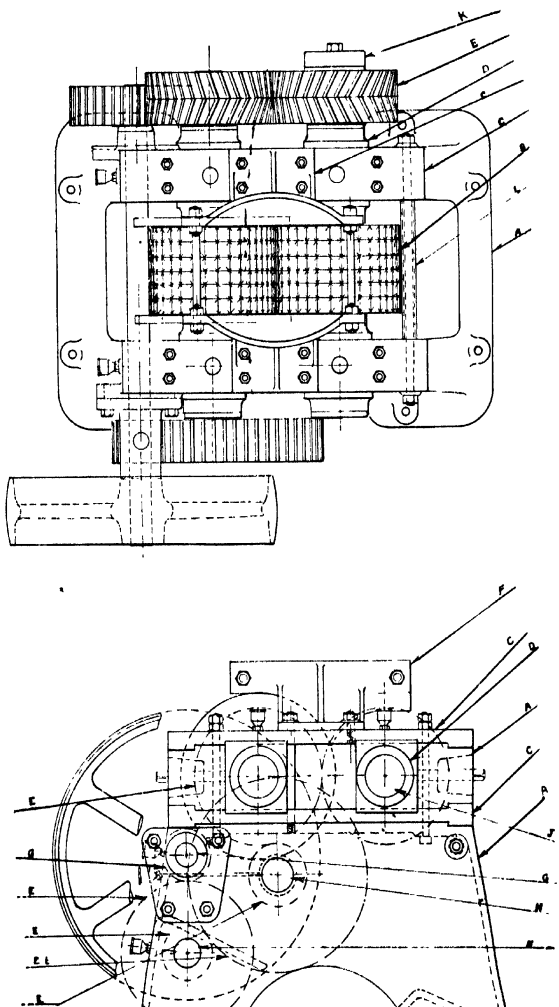

Fig. 40.—The Zwoyer Universal Press. Diagram of Operation.

quettes of anthracite coal. In the case of the peat briquettes the capacity will be considerably reduced on account of subsequent drying. The capacity can be increased by increasing the number of rows of pockets longitudinally.

A helical key on one of the main gears is a special feature of the machine. This provides a rapid and effective means for matching the pockets of the two rolls when adjusting.

Adjusting screws in the thrust blocks behind each of the roll bearings provide easy and quick adjustment of the roll centers for taking up the wear on the roll faces and in the roll bearings, also for adjusting the centre of the driven roll with relation to the intermediate driving shaft to suit the matching gear and pinion. Shims are provided between roll bearings and thrust blocks to maintain such adjustments when operating.

The triple-gear reduction permits a possible variation in the speed of the rolls from eight revolutions per minute to twenty-two revolutions per minute by changing one or both of the intermediate gear reductions but maintaining constant speed, two hundred and ten revolutions per minute, of the driving pulley. Thus higher pressures at relatively reduced tonnage are possible when desired.

The symmetrical design of the press makes right- and left-hand drives possible to suit local conditions.

Speeds up to fifteen revolutions per minute of the rolls, maintaining a pulley speed of two hundred and ten revolutions per minute, are conditions suitable for producing 15 tons of anthracite briquettes per hour. The roll speed and columnar feed should be varied to suit the material being handled and the pressure desired to avoid overloads.

One design has the following dimensions:—

5 ft. 0 in. = height over all.
6 ft. 4½ in. = length over all when using a 42-in. diameter pulley.
9 ft. 0 in. = preferred width when using a 42-in. x 10-in. pulley with clutch and outboard bearing on the side of the press adjoining the roll gears, or 8 ft. 4½ in. minimum.
8 ft. 4½ in. = width when using a 42-in. x 10-in. pulley with clutch and outboard bearing on the side of the press opposite to the roll gears.

The shape of briquette turned out by this press may be described as that shape formed by two equal size pyramids with square bases coincident and with apices and corners rounded off.

The press can be used on practically all fine materials where small briquettes are desirable. Like all tangential presses, it should, in nearly all cases, be preceded by mixing and masticating.

The Komarek Press.—The Komarek Press is a highly specialized tangential or roll press, designed by Gustave Komarek. It is installed in connection with the Dutch Process at the Berwind

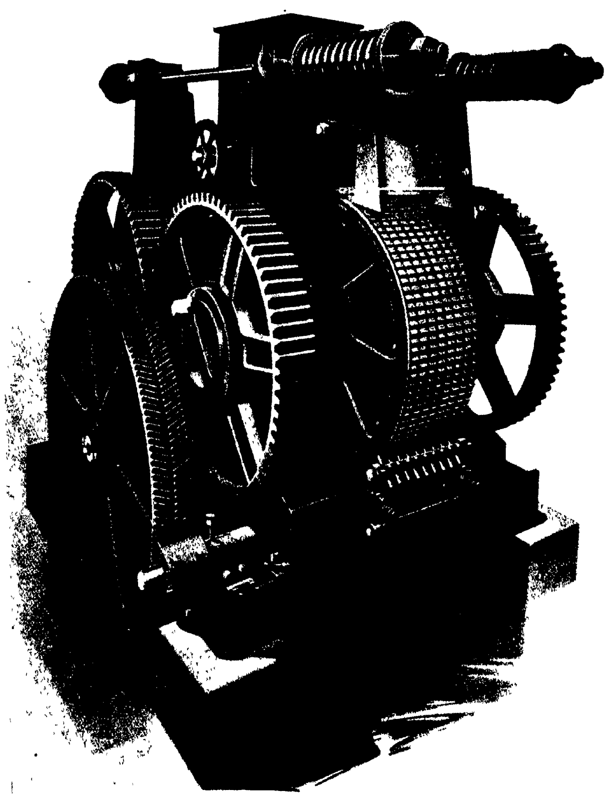

Fig. 41.—The Komarek Briquetting Press for Fuels.

Fuel Company plant for the manufacture of 2-ounce Pocahontas coal briquettes, and at the International Coal Products plant at Clinchfield, Va., for the manufacture of Carbocoal, and, in general, is the press installed for small size coal briquettes by the Malcolmson Briquette Engineering Co. It has the advantage of producing high tonnage. It is provided with sectional ring molds, whereby worn or damaged portions of the roll faces can be removed and renewed without moving the whole roll—in fact, the renewal may be a very small fraction thereof.

The diagram (Fig. 42) shows the essential characteristics of

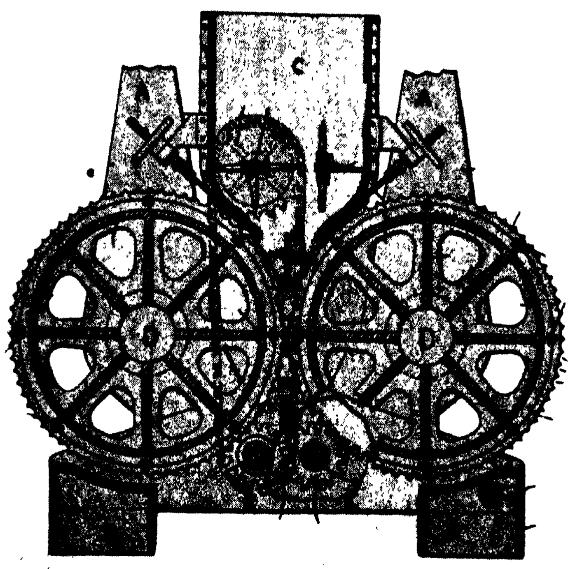

Fig. 42.—The Komarek Briquetting Press—Elevation Diagram.

the press. On a stationary base B-B are hollow shafts E-E on which are mounted loosely projecting arms A-A, which near their centers carry the bearings for the trunions of the molding rolls.

Within the hollow shafts are solid shafts, carrying intermeshing pinions, one of which transmits (through chain gear mounted

on another pinion), the motion to mixing arms located in the hopper C; while the pinion on the other shaft is enmeshed with a large drive gear wheel, and serves to transmit that drive to the large gear mounted on the roll shaft, thereby driving the rolls. The roll gears, equisized, drive the rolls in opposite directions, as in all tangential presses.

Against the upper portions of the members A-A are mounted springs, shown in the photograph (Fig. 41) but not in the diagram. These springs resist to a calculated extent any outward movement of the members A-A; but when excessive pressure through overload occurs, as for instance when a piece of iron drops into the press, the arms, carrying the rolls, move back against the springs, and breakage is prevented. The alignment of the rolls is not affected, and, the obstruction being removed, the press is ready to proceed as before.

The shape of each mold is usually an oblate semi-cylinder, slightly indented at each end—but with ends open. The briquette is, therefore, a flattened lozenge in shape, with a short but sharp narrowing in thickness at each end for a small fraction of an inch. At the Clinchfield plant of the International Coal Products Company, the shape was modified to an ovoid with flattened ends. In all cases the ends of the molds are closed by a set of stationary members S-S, set between the rolls at their point of tangency, each member consisting, essentially, of a blade or plate occurring between each rotating series of molds, forming thereby end walls for the mold cavities as the briquettes are shaped. A diminution of thickness at the lower end of these stationary members relieves the briquette from end pressure just prior to discharge, and greatly facilitates that discharge. Wear plates are inserted on these members at the pressure point, which can be renewed as needed. The nest of these members (known as mold liners) is hung from the base of the hopper—each liner extending to a Y-shape at the top—and the bottom is formed by a steel cross-piece in which the lower end of each liner is imbedded, low enough to be removed from the point of briquette discharge. (In a later design Mr. Komarek provided for movable chain, with flat links operating on a sprocket to take the place of the stationary nest of liners to form end walls for the briquette molds.)

By this improved arrangement, whether the end walls be stationary or moving, each ring with its adjacent mold liners forms a complete unit. The compression acts against the stationary liners with the same force, so it is equal and compensatory on each liner, the effect being neutralized throughout, except the two exterior spacers, where thrust blocks take up the strain.

In operation, through proper gearing connections the rolls are driven toward each other at the same speed. The stirrers in the hopper are rotated, and as the plastic mix is fed thereto it is continuously agitated and discharged downward—a homogeneous uncaked mix—and delivered uniformly into the chambers formed by the upper portions of the mold liners. Thence it fills the molds, through whose tangential contact at the horizontal centre plane of the press the necessary pressure is applied and the briquettes formed. The ends of the briquettes rub against the wear plates of the liners, preventing the escape of the material under compression. Through this method of closure uniform density is assured, it is claimed. The briquettes are discharged as usual, the discharge being facilitated by the widening space between the mold liners above described.

At the installation at the Berwind plant at Superior, Wis., the stationary mold liners have been used—the wear plates being changed every other day. At the Carbocoal plants at Irvington, N. J., and Clinchfield, Va., the moving chain of mold liners was substituted for the stationary wearing plates on account of the abrasive character of the semi-coke these briquetted.

Normally, the Komarek press is manufactured to produce 20-25 tons per hour—figured in Pocahontas coal briquettes. The drive requires about 50 horsepower.

The Mashek Press.—This design of George J. Mashek, of Newark, N. J., has been installed in all the plants erected by Mr. Mashek, among which are the following:

The Delparen Anthracite Briquette Co., Parrot, Va.

The Burnrite Fuel Co., Newark, N. J.

Northern Briquette Co., Minot, N. D., and others.

For this press has been claimed the advantages of simplicity and low cost, combined with safety of operation and easy adjustment. As in other tangential presses the main features are

rolls driven in opposite directions, containing pocket molds facing each other, whereby the briquettes are formed—the rolls being mounted in a metal frame and driven through a suitable gear reduction.

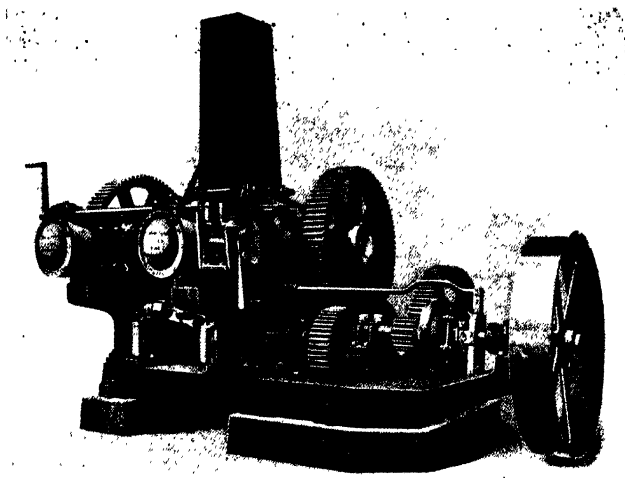

Fig. 43.—The Mashek Briquetting Press.

In the Mashek press the shape known as the "swollen pillow" is used, as opposed to the eggette on the usual Belgian presses, and differing from the Zwoyer design in the swelling at the edges.

As shown in Fig. 44, the rolls A are mounted on adjustable bearing blocks C, supported upon bearing members D secured by thrust blocks E. The bearing block of the forward rolls can be adjusted, as to its horizontal relation to the other roll, by means of a jack G, controlled by a hand wheel, locked at any desired position by a spring catch. By this regulator the thickness of the briquettes is controlled, and the surfaces of the rolls are prevented from coming in actual contact, if by chance defects develop in the spring mechanism.

Springs N are set against the forward roll pillow block,

mounted in a block M, locked by stud bolts O. The position of the bearing is regulated by a hand wheel, connecting with the spring mechanism L, through the shaft S, worm R, gear Q, and set screw P.

Thus, in operation, as the rolls A rotate against the material being briquetted, the rolls are forced against the springs, normally under 40 tons compression to each bearing—until the stops T are reached. At this point the thickest portion of the briquettes are at the compression line. The spring action then forces the return of the roll toward the other, the edges of the

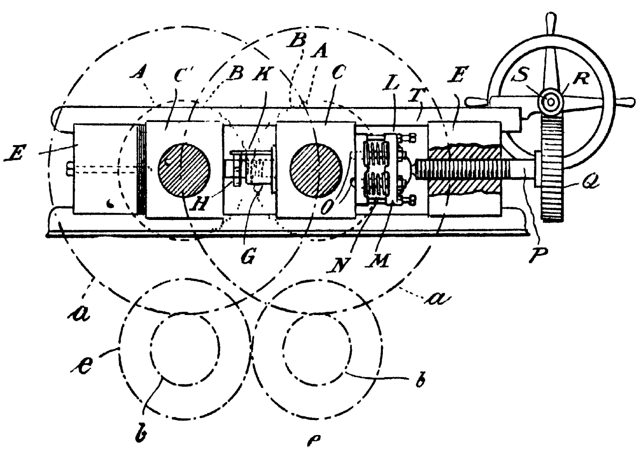

Fig. 44.—The Mashek Briquetting Press. Diagram of Mechanism.

briquettes are cut from the incoming material, and the ejection of the briquettes facilitated. This back and forth motion of one of the rolls, controlled by springs at one end and screw jacks at the other, gives a jolt to each row of briquettes after pressing is finished, cutting them off positively, and prevents sticking in the molds.

A built up hopper is used for the feed, the sides converging toward the top to prevent the flowing material from sticking at the sides. The cheek plates, set adjacent to the rolls to hold the material in the press, are provided with a renewable lining plate, covering the point of greatest wear. The material is fed directly down this hopper to the rolls.

The drive consists of pulley, drive shaft and gears. On the drive shaft is located a friction clutch adjusted to slip when the rolls are overloaded, thereby preventing breakage by cutting off the drive. A pinion on the driving shaft connects with a large gear, which meshes with the adjusting gears E, delivering the drive to the shafts C and D respectively. One of the gears E is bolted to its shaft in such a manner as to permit its limited rotation, upon release of the bolts, about the shaft—making possible the turning of one of the rolls without the other being moved. If, through wear or any other reason, the rolls are out of alignment, this feature permits an easy adjustment. The shafts CD carry the pinions BB, which engage the roll gears AA. The gears A for each roll, on account of their size, are situated on opposite sides of the press.

This press has the advantage of making very few fines on account of the shape of the briquettes.

The roll shells are designed in such a manner that they can be easily taken on and off the presses. The soft center fitting the shaft is of charcoal iron; the shells are cast from special metal, and are ground by specially designed machinery to proper smoothness.

The Mashek presses are built under trade designations as follows:

	Capacity	Size briquette	Horsepower
Type Y-1-	4½-5	1⅝-5½ oz.	10-18
Type M-1-	9-11	1⅝-5½ oz.	22-40
Type C-3	18½-22 tons per hr.	1⅝-5½ oz.	40-75

ROTARY PRESSES—MATERIAL FED HORIZONTALLY.

The Allen-Hutchinson Briquetting Press.—As shown in Figs. 45 and 46, the press consists of two rings horizontally placed and non-concentric, but one operating within the other, the periphery of the smaller one being corrugated, and facing similar corrugations on the inner periphery of the larger ring. The briquetting mixture is fed into a hopper located, usually, one-fourth of a revolution of the smaller ring from the point of maximum compression. The amount of pressure is regulated by the distance of the feed hopper from the point of maximum compression. The hopper is placed further away if greater

pressure is desired; or nearer, if the pressure is to be reduced. This simply means that more material is admitted at the greater distance, causing greater pressure. Relief from an excessive pressure is provided by two heavy springs on the outer bearings, and two over the upper pressure plate. The lower pressure plate is fixed.

In operating the press power is applied at the pulley and the material is fed into the hopper. As the material falls upon the feed ring, it is carried forward into the laterally converging space between the walls of the mold. As the space between the walls is well filled when the material leaves the bottom of the hopper the compression gradually increases, caused by the ap-

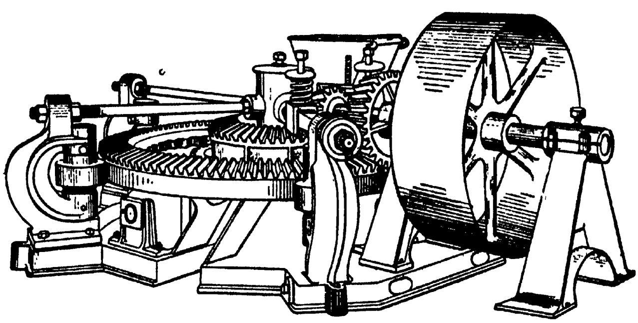

Fig. 45.—The Allen-Hutchinson Briquette Press for California Coals.

proach of the walls toward each other and the rearward movement of the material that is thus crowded back by such compression. By having the bottom move in unison with the two sides, the entire body or mass of material is fed forward with a positive movement, thereby insuring a product of a uniform density. At the instant of greatest compression, the opposing projections of the two molds are substantially in contact, and thereby sever the completed briquette from its predecessor. When the compression is complete, the recessed walls of the molds diverge, but the briquettes are still carried forward by the projections between the recesses until they reach the discharge chute, where they fall down upon the inclined bottom and are thrown out at one side of the machine.

The briquettes are approximately cylindrical in shape. They weigh from 8 to 10 ounces each, and have a specific gravity of 1.14. It was planned to reduce the size of the briquette and change its shape by having the smaller ring of the press made without corrugations.

The capacity is about 5 tons of 10-ounce briquettes per hour. One installation of this press is recorded at the Allen plant at Pittsburg, Cal.—destroyed by fire.

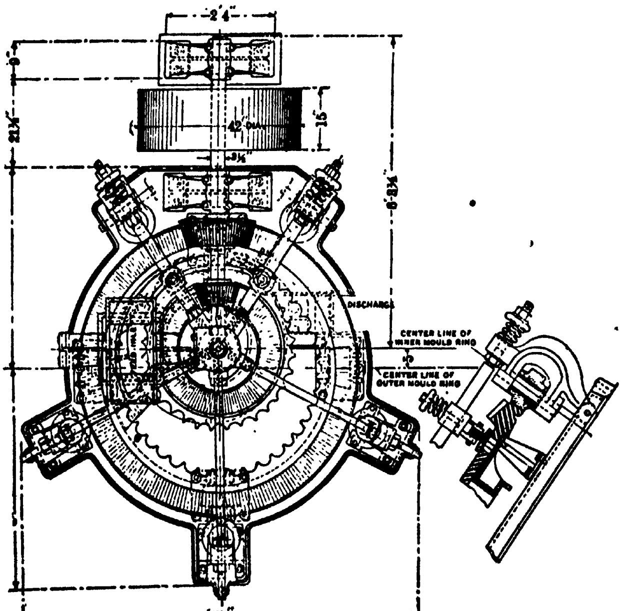

Fig. 46.—The Allen-Hutchinson Briquette Press—Plan.

The Jenkins Press.—This design was made to supplant previous Jenkins patented machines for the manufacture of peat fuel, under the auspices of the New Era Development Co. It is, however, characteristically a press, and is therefore included in this chapter. Just where a "peat machine" becomes a briquetting press is a moot point, and the dividing line of the classification is necessarily arbitrary.

This press consists of a rotating annular ring, within which rotates a wheel, not concentric with the ring. One side of the wheel operates close to the inner periphery of the ring—(this arrangement is similar to the layout of the Allen press aforementioned). This mechanism is enclosed above and below by roof and floor plates. The frame and bed plate are cast iron.

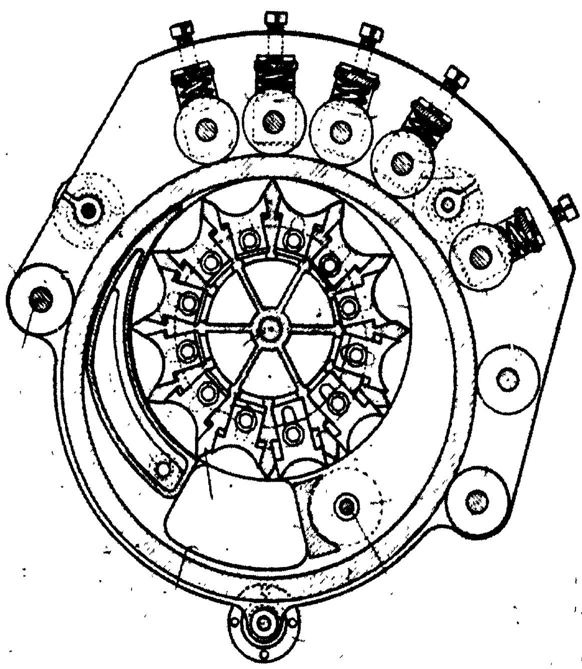

Fig. 47.—The Jenkins Peat Press.

The annular ring is surrounded partially by a series of vertically hung rollers, holding it in position. The rollers at the high pressure position are held in position by springs—overpressure induced by overloading would throw the ring against the springs at a pressure great enough to cause yielding—thereby preventing breakage.

The crescent-shaped chamber formed between the ring and the wheel is divided into two parts by a partition wall. The rotation of the wheel is counter-clockwise, so the feed is on the left side of the machine. The feed is simply a hopper, from which material is discharged into the crescent-shaped chamber by means of a feed screw. On the other side of the partition is the discharge. In the upper right horn of the crescent is a steam chest, properly piped, providing a steam-heated plate over whose surface the peat briquettes are passed after pressing, prior to discharge.

In the wheel are cut a number of radial molds in each of which is a plunger, slidably mounted, operating horizontally. Each plunger carries cam rolls engaging with cam grooves formed in the floor and roof of the press.

In operation the wheel and annular ring are rotated by a geared drive, from right to left. After passing the partition between discharge and feed, the cam movement draws the plunger back, until it is fully retracted at the pressing position. The material fed in is drawn to the left-hand horn of the crescent-shaped space—the distance between the wheel and the ring constantly narrowing. These converging surfaces compress the material into the mold pockets. For a period the ring and the wheel are nearly in contact, and here the maximum pressure is brought to bear upon the pressed masses, the annular ring closing the open side of the molds.

As the surfaces of ring and wheel diverge beyond the pressing position, the material, still in the molds, is brought in contact, on the open face, with the side of the steam chest. The steam chest is stationary, and the material is scraped along its surface. The result is a drying action which removes moisture from the briquetted blocks and incidentally prevents their sticking in the molds.

After passing the steam chest, the cam system throws each plunger outward, ejecting the briquette. The empty mold passes the partition and enters the feed area again.

The briquettes are shaped like pig metal ingots.

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CHAPTER III.

THE BRIQUETTING OF STEEL SWARF AND TURNINGS.

Briquettes in the Open-Hearth and Electric Furnace—Steel Swarf Usually Tangled and Admixed with Heavy Scrap—Means Taken to Separate Heavy Scrap, Disentangle and Cut Up Light Scrap—Plant of the Ohio Metal Briquetting Co., Cleveland, Ohio—Steel Briquetting on Ronay Presses Steel Briquetting by the Hot Method.

Every machine shop is a producer of steel turnings. The rough shapes—whether castings, forgings or rolled material, must be turned down by lathe, planner or other machine to the size required. The amount of swarf— a generic term for all light metal

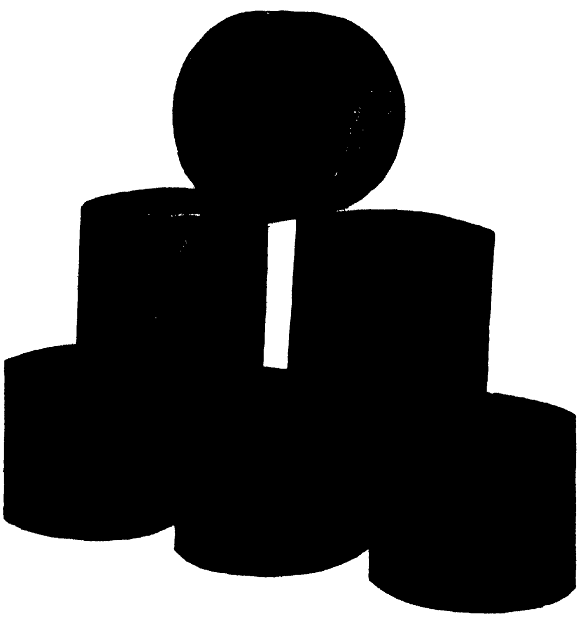


Fig. 48.—Typical Steel Briquettes. Made in Germany by the Ronay Process.

scrap—so produced is enormous. Its disposal has been a problem. Not a little of it has heretofore been returned to the blast furnace. Indeed, some blast furnace superintendents have welcomed it,

claiming its use has been beneficial to furnace operation. None the less the price the blast furnace can afford to pay for turnings is far below their value.

Steel swarf should go to the electric furnace or the open-hearth. It should displace in the charging boxes a percentage of pig and heavy melting steel for the manufacture of the billets that are the product of that furnace. But transportation and handling of the tangles of light steel scrap—with a bulk far beyond the metal tonnages that might reasonably be expected to occupy that

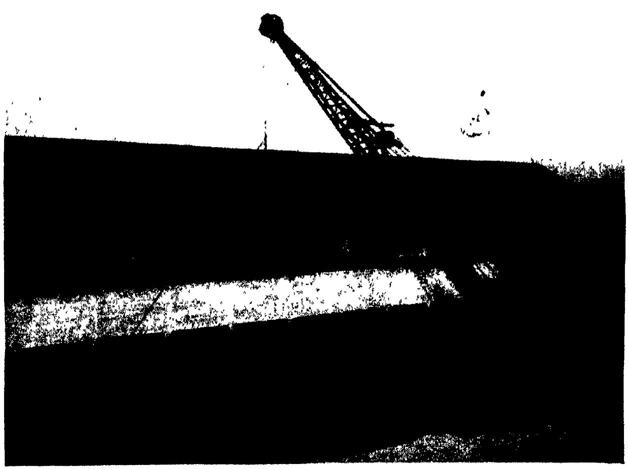


Fig. 49.—Steel Briquetting Plant of the Ohio Metal Briquetting Company, Cleveland, Ohio. Unloading Steel Turnings into Bins.

bulk—is expensive. Loading charging boxes with swarf for open-hearth use is accompanied by like embarrassment. Production is hampered by the difficulty in cramming the material into small compass in the boxes, hence a large number of boxes is required. There follows a difficulty in charging into the furnace. Time is lost in charging while the mass melts down. Further, the melting is accompanied by excessive oxidation losses—up to 40 per cent of turnings charged, due to the great surface of metal exposed

to oxidizing action. Such disabilities are reflected in the cost of materials and it is by no means unusual for the market report to quote swarf at less than half the price of the heavy scrap metal.

The fabrication of such material into 20-pound briquettes, almost solid cylindrical blocks of steel, has been done successfully at several places in Europe and notably in the Cleveland district in the United States of America. The briquettes are an ideal product for charging into the open-hearth furnace. Because of their regu-

Fig. 50.—Stock Pile of Steel Turnings. Ohio Metal Briquetting Company, Cleveland, Ohio.

larity of shape, they may be more conveniently charged than the ordinary run of scrap. They are loaded into charging boxes with the electric magnet far more readily and effectively and in larger loads per box. When charged into the furnace they are more compact, require less time for charging and when melting down do not "stick up" along the side walls of the furnace, but on the contrary immerse themselves in the bath rapidly. They melt from the outside and the melting losses compare most favorably with the best open-hearth practice. On account of the greater facil-

ity in handling and charging, briquettes obtain premium over the market price of heavy melting steel.

The plant of the Ohio Metal Briquetting Company at Cleveland, Ohio, has successfully furnished steel briquettes to the open-hearth market in Cleveland for the past two years; and a description of the machines and methods there employed is in effect the story of steel swarf briquetting in America to-day.

The incoming turnings are delivered in flat-bottomed gondolas,

Fig. 51.—Installing Ronay-Gilmore Presses. Ohio Metal Briquetting Company, Cleveland, Ohio.

and those which cannot be worked up immediately are stocked in the open yard. The material as delivered consists of a mixture of long turnings, usually in tangled masses, mixed with a percentage of short turnings (known to the trade as "shoveling turnings") and a very fair-sized and annoying sprinkling of heavy scrap—bolts, nuts, defective work and the like. In such shape the swarf cannot be handle' efficiently by the presses, so the mats must be torn apart to feed into the press hoppers. Even then it is difficult to feed the long turnings into the mold. The

bulky masses would make thin and light briquettes and the output would be seriously reduced. In addition, the admixture of heavy scrap causes frequent stoppages of the press, unnecessary wear of the molds and adds an element of danger to the machinery. Consequently it is necessary that the material be disentangled, chopped into short lengths, and freed from the admixture of heavy scrap before it is a suitable feed for the briquetting press. To supply this ideal press feed a preparation plant was developed.

The turnings either from stock pile or cars are dumped into an overhead bin, with sloping bottom and furnished with gate bars on one side. The turnings are passed through the bin gate to a

Fig. 52.—Typical Run of Steel Briquettes. Ohio Metal Briquetting Company, Cleveland, Ohio.

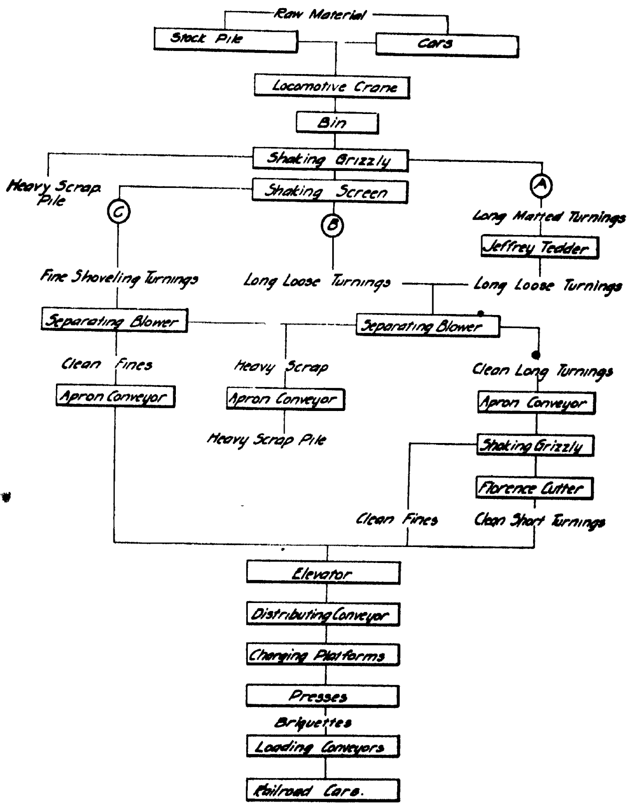
shaking classifier, which is a combination grizzly and screen. Both are actuated by means of eccentrics, and, being inclined, a continuous discharge is effected.

The division made is three fold.

(A) Over grizzly—tangled long turnings plus large, heavy steel scrap.

(B) Over screen—long turnings plus heavy steel scrap, which passes through the grizzly, but is too large to pass through the screen.

(C) Through screen—short turnings plus small heavy steel. Material A—must be disentangled, and broken down somewhat



Flow Sheet—Ohio Metal Briquetting Co.

in order to release any heavy scrap held and for the cutting operation to follow. For this purpose a machine, somewhat similar to a coal crusher has been developed. The rotor is provided with suitable teeth or projections and the stationary plate with retarding members. The machine does not have a shear-

ing or cutting action, but rather a tearing effect, and is conveniently referred to as a "tedder." The amount of oversize heavy steel that fails to pass through the grizzly is so small that the attendant of the tedder removes it by hand without difficulty. If any passes his vigilance the machine is stopped by the breaking of a shear pin. Thereupon the obstruction is removed, the shear pin replaced in a few moments and the operation proceeds.

Material A, disintegrated by the tedder, and material B, the turnings that have passed through the grizzly, both over the size of "shoveling turnings," with the accompanying heavy scrap, are brought separately by conveyor before the nozzles of a low pressure air blower. The materials are dropped vertically in a thin but wide stream in front of the air blast, the velocity of which deflects the light turnings into an air chamber. At the bottom of this chamber is an apron conveyor which discharges into the cutting machine. The heavy material is carried by means of a cross conveyor to a separate storage pile for resale as heavy melting steel.

These turnings, now separated from the heavy scrap, must be cut up before being fed to the press. They are conveyed to what is locally known as a "Florence Cutter"—the invention of Thomas Gilmore, Jr. This machine is essentially as follows: A hopper surmounts a set of two or more feeding and shredding rolls, which tear apart any surviving mats, contribute to the breaking down of the turnings and insure an even feed to the cutter below. The shredding rolls may or may not be used as the occasion warrants.

The cutter proper consists of a series of rectangular lugs or knives set in a platen, whose position is adjusted by a crank operated by hand, and set prior to machine operation. These knives are removable for the purpose of renewals, and are made of high grade steel. A drum, revolving before the knife platen, carries a series of knives or lugs, so set in the drum that their cutting between the stationery knives is in sequence, no two passing through coincidentally.

The A and B mixture, after removal of the heavy scrap, is fed into this machine, straightened and proportioned by the feed

mechanism and cut up into short lengths, ideal for the purpose of press feed. The machine is safeguarded by the use of shear pins. The product is conveyed directly to the press elevator.

Meanwhile product C, the "shoveling turnings" that have passed the grizzly and screen that form the initial part of this operation, pass, with their accompanying admixture of small heavy metal, before the nozzle of a blower. The division of the light turnings from the heavy metal proceeds exactly as at

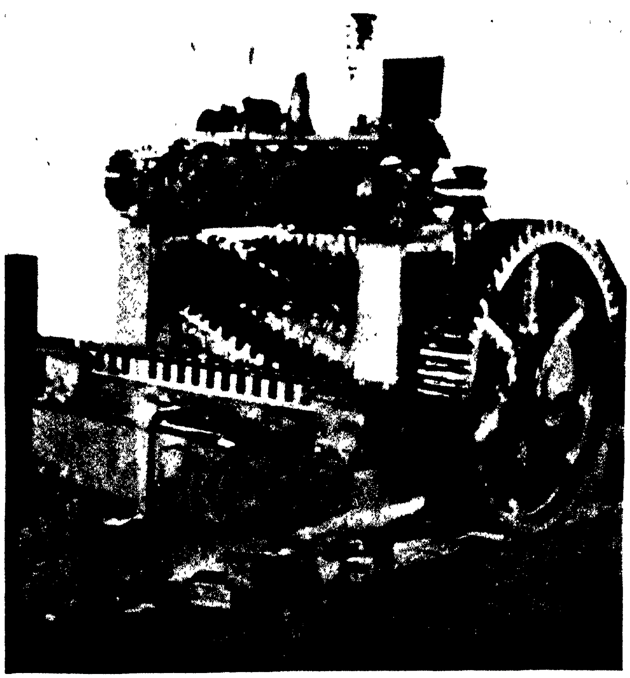


Fig. 53.—Gilmore Shredder and Cutter for Metal Turnings (Outer Casing Removed). Ohio Metal Briquetting Company, Cleveland, Ohio.

Nozzle 1, and the heavy melting scrap is carried to the same storage as above mentioned. The shoveling turnings are mixed with the turnings which passed through the cutting machine, and conveyed to the press for briquetting.

The press equipment consists of four Ronay-Gilmore type (previously described) presses, operating in parallel, actuated each by a horizontal duplex double-acting pump. The entire plant operates electrically, each unit being driven directly by two motors. The briquettes are loaded by conveyors directly into railroad cars. They stand transportation well and are in good demand on the part of open hearth operators. The porosity is 30-35 per cent.

In Europe the development of steel and cast iron briquetting has been going on for several years. In 1910 there were two

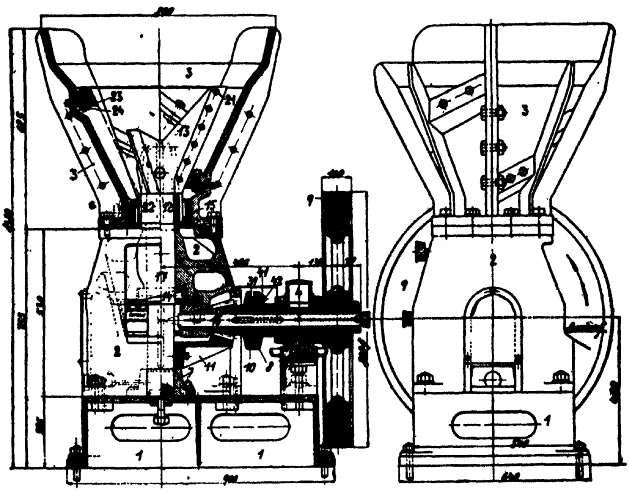


Fig. 54.—The Philip System (German) for Cutting up Metal Turnings. Diagram.

plants operating in Berlin; one each in Chemnitz, Stolberg, Cassel and Kiel in Germany, and the process was also represented in Austria-Hungary, Italy and Switzerland. In all of these operations a plentiful supply of small size chips has been at hand and the operation of cutting and separation required in the Ohio Metal Briquetting Company's plant has not been necessary. However, there has been constantly a demand for a machine in Europe for cutting up long turnings prior to briquetting, as there has been in the United States, and the System Philip has made quite some progress in that direction. This machine is illustrated in Figure 54. This crusher consists of a large funnel equip-

ped with spiral ribs running toward the centre, forming channels with a corkscrew effect, increasing in number but diminishing in size as the lower portion is approached. Operating against these ribs is a series of ribs wound spirally about a roller. With the uniform distribution of both sets of ribs, a uniform distribution of cuttings in each of the machines is obtained; for example, operating at thirty revolutions per minute a machine constructed with eight ribs in the funnel and twenty upon the roller will make 4,800 cuttings per minute. It is claimed that the machine operates with but little wear and tear and the wearing parts

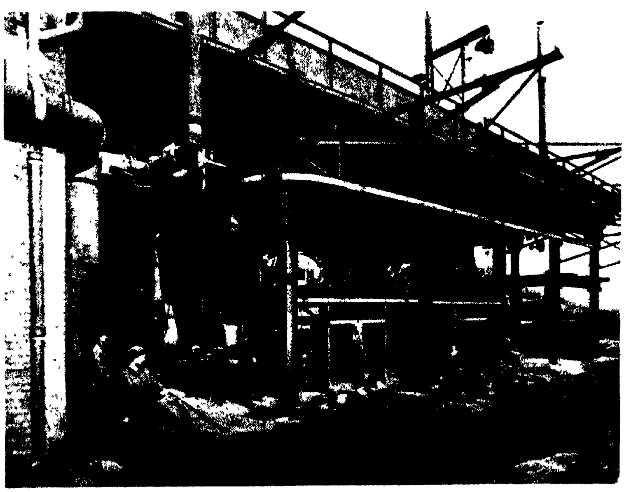


Fig. 55.—A German Plant for Briquetting Steel Swarf by the Hot Method. The Rotary Heaters are shown at Discharge End in the Centre. At the left is the Drop Hammer which Forms the Briquettes.

are of hardened steel and easily accessible for changing. The knives on the cutter are exchangeable as well. The space required is said to be 1 square yard. The power required is 3 to 10 horsepower. The company manufacturing is now making a larger pressure with a capacity of 3 tons per hour, requiring 25 horsepower to run. No installation of this machine has as yet been made in the United States.

In Germany recently there has been a very considerable experiment on the lines of what is known as hot briquetting, which deserves mention. The departure from usual methods is radical. The turnings are carried to a high platform and there charged into rotary furnaces, which burn off all carbonaceous or hydrocarbonaceous matter, including oil, and heat the charge to a red heat. Thence they are discharged into a mold under an air hammer, which delivers one or more strokes to the hot chips in the mold. The diameter is 10 inches usually—sometimes a mold of 8½ inches is used. It will be seen that this briquette is larger and heavier than the usual hydraulic press briquette.

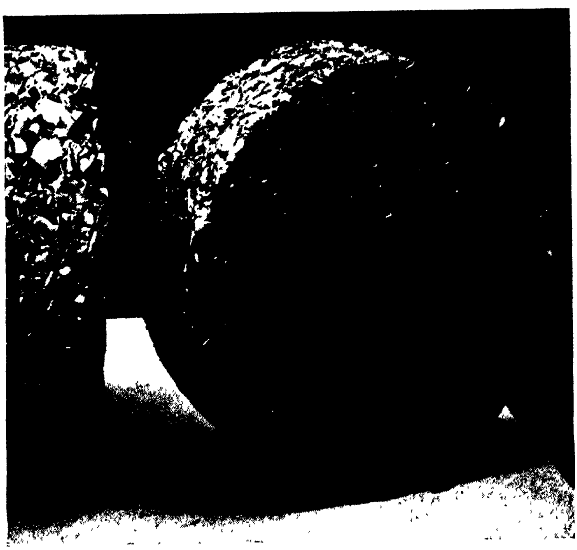


Fig. 56.—Typical Hot Process Steel Briquette.

The furnaces are heated with gas. The hammer is of special design known as the Keutzer. Information to hand in this country as to this process is extremely meager. The cut (Fig. 55) shows the ends of the furnaces delivering the loose metal, and a die and hammer at the inner end. The briquettes are shown in the foreground. It is noted, too, that the hot metal is carried over tracks in a small car from the furnaces to the hammer. On cooling, the briquettes are ready for market.

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CHAPTER IV.

THE BRIQUETTING OF CAST IRON BORINGS.

Cupola Practice With Cast Iron Briquettes—The Briquetting of Cast Iron Borings—The Roll Press Applied to Cast Iron Borings.

The melting of cast iron borings has always been a source of trouble in foundry practice. In fact, a great many shops sell borings direct to the blast furnace, where they are highly prized as an addition to the charge on account of their cleansing qualities. Such practice is, unquestionably, wasteful, and the use of borings directly in the cupola with minimum loss and without impairing the quality of the product has been the object of

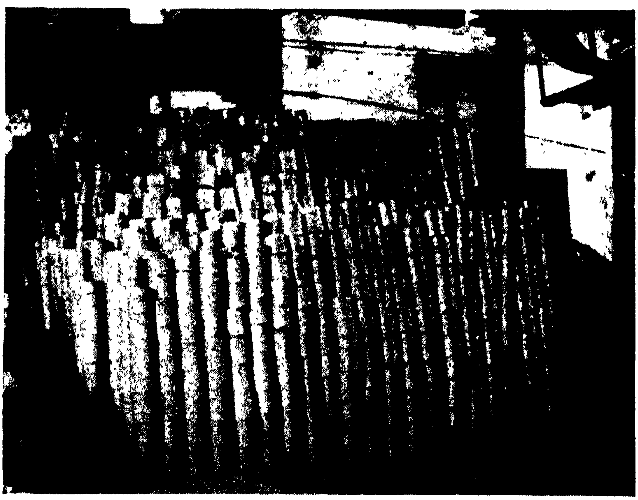

Fig. 57.—Pile of Cast Iron Briquettes Made by the Ronay Process at Chemnitz, Saxony. Briquettes 6¼ Inches Diameter by 7 Inches High. They Weigh about 38 Pounds Each.

much study. The charging of borings as such into the cupola results in heavy metal losses and in a burning out of carbon and silicon, to such an extent that the product approaches low quality white iron. An improvement has been made by boxing the borings, and in some cases placing them in an iron pipe and gradually lowering into the melt, the pipe melting with its contents. Great care must be exercised to prevent a break in the container in applying such methods.

In Europe the application of briquetting to cast iron borings has met with a very considerable success. H. Furth (*Giesserei Zeitung,* Vol. IX, pp. 105-107, 149-155) summarised the practical experience gained in the last few years in using briquettes of iron and steel turnings in the cupola. Foundrymen at first encountered difficulties in their use as an addition to the cupola charge; but by chemical control of the foundry practice and careful study of the

Fig. 58.—Charging a Foundry Cupola with Cast Iron Briquettes. Borsig Works, Berlin, Germany. These are Ronay Process Briquettes, and are Being Charged by Hand. In Foundries in this Country the Same Type of Briquette is Dumped into the Cupola in Loads. The Briquettes Stand this Treatment very Well.

analyses, the working with briquetted borings was standardized. It was found that chemical changes occur in melting, which impart to cast iron made with briquettes the characteristics of white iron—where too great a proportion of briquettes are used in the charge. This action takes place in the higher zones of the cupola, where the briquettes in a red hot condition encounter the full effect of the air blast. A large proportion of the graphite

burns out, and a great loss of silicon, about 25 per cent of the total, takes place. The briquettes, on account of their porous structure, take up more sulphur from the gases than the ordinary metal charge. It is best to charge the briquettes last, so as to avoid breakage so far as possible. Difficulty was formerly experienced in getting the larger batches of briquettes to melt, but if the melting zone is not too high, and the heat is well concentrated, they will be fused readily enough. It is certain that briquettes can seldom be used to form 100 per cent of a cupola charge, or even 50 per cent. However, where smaller proportions are used—between 10 and 20 per cent of the charge—the disabilities above mentioned are no longer in evidence, and excellent iron can be made.

A very considerable interest in briquetting borings has been aroused in the United States. A complete series of tests was run with the co-operation of the Southwark Foundry and Machine Co. and the Baldwin Locomotive Works (during May) by Thomas Gilmore, Jr., chief engineer of the General Briquetting Co., New York. The object of these tests was to show the effect of the admixture of briquetted cast iron borings upon the cupola product.

The cast iron borings from which the briquettes were made on this run were medium cut assorted borings made at the foundry of the Baldwin Locomotive Works. The briquettes were made on a Ronay-Gilmore press. They were 5 inches in diameter and uniformly between 7 to 8 inches high, weighing about 28 pounds each. The density was about 80 per cent the normal density of iron. In this experiment it was desired to show that an admixture of 10 to 20 per cent of briquettes to the regular scrap and pig charge in the cupola would give a metal adapted to the purposes required.

Accordingly, two series of tests were arranged: one on the miscellaneous mixture and the other on locomotive cylinder mixture. The regular mixture for miscellaneous casting consists of 60 per cent scrap and 40 per cent pig iron. The cast iron for locomotive cylinders (the regular mixture) is made from 50 per cent scrap, 10 per cent car wheels, and 40 per cent pig iron. It was especially desired to show that the use of briquettes would justify lowering the per cent of pig iron required. Four mixtures were made of each class of material, the total weight of each charge being 3,000 pounds. In the miscellaneous mixture, No. 1

consisted of 10 per cent briquettes, 60 per cent scrap and 30 per cent pig iron, the briquettes, therefore, taking the place of pig iron in the melt. In test No. 2 10 per cent briquettes, 50 per cent scrap and 40 per cent pig iron were used, the briquettes taking the place of the scrap. In test No. 3, 20 per cent briquettes, 50 per cent scrap and 30 per cent pig iron were used, the proportion of briquettes being divided between the scrap and the pig iron, 10 per cent of each being substituted. In the case of the locomotive cylinder mixture four tests were also run—one of the regular mixture as above. Test mixture No. 1 consisted of 10 per cent briquettes, 50 per cent scrap, 10 per cent car wheels and 30 per cent

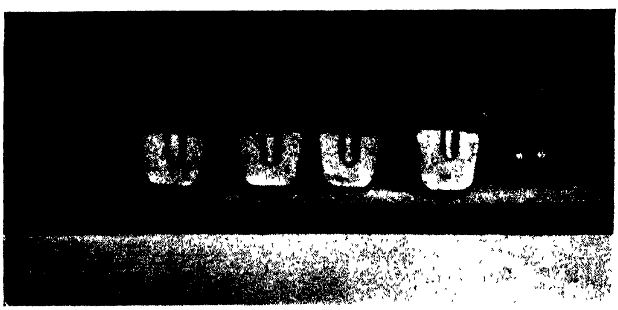

Fig. 59.—Fractures of Test Pieces of Cast Iron Made from Various Mixtures, Some Containing Briquettes, at the Baldwin Locomotive Works.

No. 1. *Regular Cyl. Iron.* Pig Iron 40 Per Cent. Car Wheels 10 Per Cent, Iron Scrap 50 Per Cent.

No. 2. *Cyl. Mixture.* Pig Iron 30 Per Cent, Car Wheels 10 Per Cent, Scrap 50 Per Cent, Briquettes 10 Per Cent.

No. 3. *Cyl. Mixture.* Pig Iron 40 Per Cent, Car Wheels 10 Per Cent, Scrap 40 Per Cent, Briquettes 10 Per Cent.

No. 4. *Cyl. Mixture.* Pig Iron 30 Per Cent, Car Wheels 10 Per Cent, Scrap 40 Per Cent, Briquettes 20 Per Cent.

pig iron, the briquettes in this case taking the place of the pig iron. Similarly test No. 2 contained 10 per cent briquettes, 40 per cent scrap, 10 per cent car wheels and 40 per cent pig iron, the briquettes taking the place of the scrap, while in test No. 3, 20 per cent briquettes were used, 40 per cent scrap, 10 per cent car wheels and 30 per cent pig iron, the briquettes taking the place of 10 per cent heavy scrap and 10 per cent pig iron, respectively. The per cent of car wheels was the same in each mixture. The tabulation of the charges was as shown in Table V.

burns out, and a great loss of silicon, about 25 per cent of the total, takes place. The briquettes, on account of their porous structure, take up more sulphur from the gases than the ordinary metal charge. It is best to charge the briquettes last, so as to avoid breakage so far as possible. Difficulty was formerly experienced in getting the larger batches of briquettes to melt, but if the melting zone is not too high, and the heat is well concentrated, they will be fused readily enough. It is certain that briquettes can seldom be used to form 100 per cent of a cupola charge, or even 50 per cent. However, where smaller proportions are used—between 10 and 20 per cent of the charge—the disabilities above mentioned are no longer in evidence, and excellent iron can be made.

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In all cases, the deflection at 1,000 pounds was the same and there is little difference at 2,000 pounds, and though mixture No. 3, in each case, shows a greater deflection at 3,000 pounds than does the regular mixture, it is hardly enough to draw a definite conclusion. The rupture would seem to indicate that the use of briquettes had increased the resistance of the iron progressively in proportion as the briquettes were used, there being a difference of 600 pounds at rupture between the regular mixture and mixture No. 3. On the other hand, the cylinder mixture shows a decrease under the same conditions, although it should be noted that the average breakage point of the three test pieces is 3,930 pounds, while that of the regular mixture was 4,000 pounds—certainly not a difference of any great moment. The results of tensile tests are shown in Table VII.

With the exception of miscellaneous iron test piece No. 2, which failed under comparatively light load, the result expressed in breaking strength per square inch was uniform and would indicate, so far as tensile resistance is concerned in these mixtures, that the use of briquettes has little influence one way or the other.

The conclusion is, therefore, that briquettes of cast iron have a very definite and promising future in foundry practice. It seems conclusive that, used in moderation, they in no way injure the resulting melt and their use results in very great economy.

TABLE V.

MATERIALS USED IN TEST MIXTURES

CAST IRON FOR MISCELLANEOUS CASTINGS

	Briquettes		Scrap		Pig iron		Total weight of charge
	Pounds	Per cent	Pounds	Per cent	Pounds	Per cent	Pounds
Regular mixture	...	..	1,800	60	1,200	40	3,000
Test mixture No. 1	300	10	1,800	60	900	30	3,000
Test mixture No. 2	300	10	1,500	50	1,200	40	3,000
Test mixture No. 3	600	20	1,500	50	900	30	3,000

The analysis of the pig iron was as follows: Silicon, 2.6 per cent; phosphorus, 0.08 per cent; and sulphur, 0.03 per cent. The scrap was mostly foreign material; the analysis of this material can be assumed as: Silicon, 1.8 per cent; phosphorus, 0.7 per cent; and sulphur, 0.09 per cent.

CAST IRON FOR LOCOMOTIVE CYLINDERS

	Briquettes		Scrap		Car wheels		Pig iron		Total weight of charge
	Lbs.	Per cent	Lbs.	Per cent	Lbs.	Per cent	Lbs.	Per cent	Lbs.
Reg. cyl. mix	...	..	1,500	50	300	10	1,200	40	3,000
Test mix. No. 1	300	10	1,500	50	300	10	900	30	3,000
Test mix. No. 2	300	10	1,200	40	300	10	1,200	40	3,000
Test mix. No. 3	600	20	1,200	40	300	10	900	30	3,000

Hard and dense West Virginia coke containing 0.8 to 1 per cent sulphur was used. One part of coke to 8 or 9 parts of iron was used. The inside diameter of the cupola was 54 inches and the melting capacity was about 15,000 pounds per hour.

TABLE VI.
RESULTS OF TRANSVERSE TESTS

	Diam. Inch.	Deflection at 1,000 Pounds	2,000 Pounds	3,000 Pounds	Rupture Pounds
Miscel. iron, reg. mix	1.29	0.05	0.09	0.10	3,000
Miscel. iron, test No. 1	1.29	0.05	0.09	0.11	3 400
Miscel. iron, test No. 2	1.31	0.05	0.085	0.10	3,550
Miscel. iron, test No. 3	1.284	0.05	0.09	0.11	3,600
Cyl. iron, reg. mix	1.291	0.05	0.09	0.11	4,000
Cyl. iron, test No. 1	1.338	0.04	0.08	0.10	4,400
Cyl. iron, test No. 2	1.281	0.05	0.085	0.11	3,700
Cyl iron, test No. 3	1.28	0.06	0.09	0.12	3,700

TABLE VII.
RESULTS OF TENSILE TESTS

	Diam. Inch	Area Sq. in.	Breaking strength Pounds	Stress per Sq. in.
Miscel. iron, reg. mix	0.786	0.485	15,100	31,140
Miscel. iron, test No. 1	0.792	0.493	15,300	31,030
Miscel. iron, test No. 2	0.805	0.509	12,100	23,770
Miscel. iron, test No. 3	0.763	0.457	14,100	30,850
Cyl. iron, reg. mix	0.744	0.435	14,300	32,880
Cyl. iron, test No. 1	0.795	0.496	18,700	37,700
Cyl. iron, test No. 2	0.776	0.473	16,700	35,310
Cyl. iron, test No. 3	0.778	0.472	15,600	32,840

As is well known, there is a very large differential between the cost of light borings and heavy iron scrap. It can be confidently predicted that briquettes, as a part of melting mixtures, will be standard practice in future.

A stimulus to the use of cast iron briquettes in the iron factory is anticipated in the growing popularity of what is known as duplex practice. By duplex practice of melting is meant the use of the cupola as the primary melting unit followed by an

electric furnace into which the molten iron is poured and purified. Dr. Richard Moldenke has outlined this practice in a paper before the American Institute of Mining Engineers during the past year. The castings run through the duplex system are improved in respect to combined oxygen and sulphur. If this practice becomes general, undoubtedly the percentage of briquetted borings may be considerably increased beyond the 20 per cent now considered the outside limit for good iron.

The bulk of this chapter has been taken up with the metallurgical or melting aspect of briquetted foundry borings. The actual briquetting does not involve great difficulties. On cheap material of this nature the briquetting engineer cannot work under as wide margins as in the case of non-ferrous metals. On the other hand, but little preparation is ever necessary. Where high pressures are used, briquettes have been made quite successfully by feeding the dry borings directly to the press. The Duryea press (see Chapter II) has been used with success in Chicago by the American Block and Ingot Company. The Federal Briquetting Company of Illinois has made an excellent product in their custom plant in Cincinnati, using a Jacomini press (see Chapter II). The Worthington Pump & Machinery Corp. has an installation of a Gilmore horizontal press at Harrison, N. J. In Germany the Ronay press has been used for years, notably, at the Borsig Locomotive Works and, laterally, the hot briquetting methods (with Drophammer) (described in Chapter III) have been found applicable to cast iron borings.

Despite the high pressures used, in nearly all cases a better product can be obtained, a better bond secured, by moistening the borings slightly before briquetting. A slight incrustation of ferric oxide, not sufficient to be felt in the cupola practice, forms, and is a binder of no mean efficiency. More rapid formation of this bond is obtained by the use of salt water—a practice, however, which requires care, as it is easy to overdo the saline admixture, with consequent over-production of oxide. Loading, transportation and charging in the cupola—in brief, all the mechanical requirements—are fully met by the briquettes as well as in the case of steel. On the other hand, cast iron briquettes, limited to 20 per cent of the cupola charge, by reason of the dis-

abilities described, can never command a premium, as do steel briquettes, but, on the contrary, are at a small discount as compared with high grade large scrap of similar analysis.

Fig. 60.—Cast Iron Borings Briquetted on Universal Press.

Until the past year there has been little effort made to adapt roll press practice to cast iron briquetting. The development of the Universal press with the self-feeding feature of the rolls (see Chapter II) has rendered such briquetting in every way commercial. However, the cast iron borings cannot be fed dry to this type of press without developing dangerous and even prohibitive pressures. It has, therefore, been found the part of wisdom to admix a small proportion—2 to 3 per cent—of acid sulphite liquor in order to insure proper press action and the highest possible grade of briquette. This is in effect a duplex binder as described in Chapter VI. The gummy portion of the sulphite liquor holds the briquette together after it is discharged from the press, while the action of the acid is going on, forming the small

proportion of ferric oxide which is the true and final binder. A very considerable heat is evolved during the course of manufacture sufficient to dry thoroughly, rendering the briquette waterproof.

In this practice the lamination or stratification common to all forms of piston and mold briquettes is avoided and there is no danger of corners chipping and breaking off, which is especially a feature of dry briquetting by any of the foregoing methods. The briquettes are exceedingly strong, and, while they must still be held within the 20 per cent maximum, will give the utmost satisfaction in cupola practice, if used in proportions below that. It is the writer's belief that the future of the disposal of cast iron borings will lie in their briquetting by this or a similar method. The roll press is far cheaper of operation than any other type. The mixing is not difficult and can be accomplished by a pug mill or a cement mixer, preceding the press, into which proper proportions of both ingredients can be poured in regular streams. Such an installation, including the press, would cost less than $10,000.00 and could treat 10 tons per hour at 1921 prices.

It may be of interest to quote the following from *McClure's Magazine*, June, 1920:

"There was a steel mill in the middle west that collected enormous quantities of cast iron chips and borings. They were worth about eight dollars a ton, and I bought them at that price. The factory had tried to use them, all the more so because pig iron was worth $48.00 a ton then. It was impossible to melt the chips and borings; they were so small that they simply burned up. Well, I bought them, not knowing just what to do with them. I pressed them into briquettes, and in that form I found that they could be melted up readily enough. That netted me $93.75 a day. Afterward, the mill found out what I was doing, kept the scraps, and briquetted them itself."

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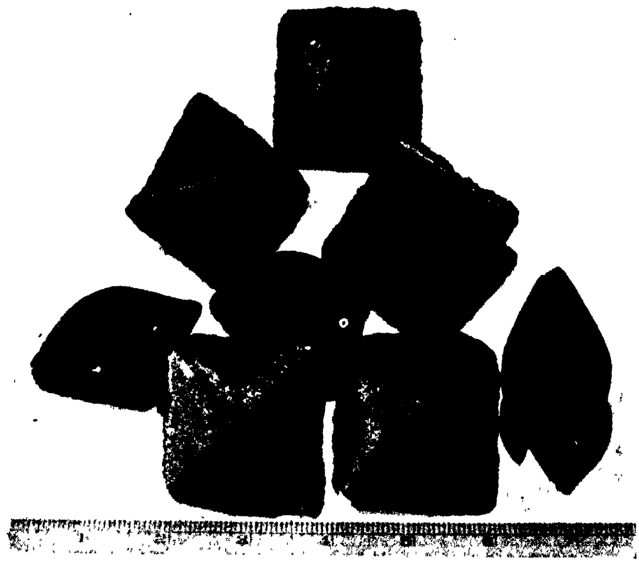

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CHAPTER V.

THE BRIQUETTING OF NON-FERROUS METALS.

Difficulties of Melting Brass and Bronze Swarf—Comparative Tests in Melting Briquettes and Loose Swarf—Methods of Preparation and Briquetting Cuprous Swarf—Notes on Briquetting Applied to Melting Aluminum Chips

In the manufacture of brass, bronze and other non-ferrous alloys, the light metal swarf problem is even more acute than is the case in steel and cast iron melting. The losses engendered in handling and melting the swarf of these metals run into high figures, not only on account of the far higher cost of the metals used, but because of the low volatilizing temperature of certain metals concerned, notably zinc. In some plants borings and other swarf are run into ingot before being added to the regular metal charge—a costly duplex operation, justified only on the ground of superior product. The majority of brass manufacturers report using 15 to 25 per cent of their borings in their regular charges. Some, having specialized in careful melting to a high degree, operate on borings and turnings purchased in the open market.

The methods of melting are two:

1. Crucible or furnace melting.
   (Direct heat methods)
2. The electric furnace.
   (Electric melting)

H. W. Gillet in "Brass Furnace Practice in the U. S." *Bulletin No. 73*—Bureau of Mines—gives the following complete classification of Direct Heat Furnace: (Class 1 above).

The following list covers practically every method of melting non-ferrous metals, including crucibles of various sorts—tilting, reverberatory and open-hearth furnaces, with the single exception of the electric furnaces which are now coming very rapidly into vogue. It is claimed for electric furnace melting that the heat control is very simple and the ease of operation and general cleanliness are far superior to any method of direct fire melting. It has been shown that the metal losses by electric furnace melting are very considerably red.ced. The metal produced is at least equal to that produced in crucible melting and the cost of operation is said to be lower and the capacity higher. The only

GENERAL TYPES OF FURNACES IN USE

No.	Gen'l. designation of type of furnace	Kind of draft	Fuel burned
1	Pit	Natural	Coke
2	Pit	Natural	Anthracite coal
3	Pit	Natural	Both coke and coal
4	Pit	Natural	Both coal and charcoal
5	Pit	Forced	Coke
6	Pit	Forced	Coal
7	Pit	Forced	Both coke and coal
8	Tilting	Forced	Coke
9	Tilting	Forced	Coal and coke
10	Pit	Natural	Oil
11	Pit	Burner	Oil
12	Pit	Burner	Natural gas
13	Pit	Burner	City gas
14	Pit	Burner	Producer gas
15	Tilting	Burner	Oil
16	Tilting	Burner	Natural gas
17	Tilting	Burner	Producer gas
18	Pit	Natural	Bituminous coal
19	Pit	Burner	Oil
20	Pit	Natural	Oil
21	Open-flame tilting	Burner	Oil
22	Open-flame tilting	Burner	Natural gas
23	Reverberatory	Burner	Oil
24	Reverberatory	Natural	Bituminous coal
25	Reverberatory	Forced	Bituminous coal
26	Cupola	Forced	Coke
27	Cupola	Forced	Charcoal
28	Reverberatory	Burner	Producer gas
29	Reverberatory	Natural	Oil
30	Open-flame tilting	Burner	City gas

NOTES

Types 1 to 20 use crucibles; types 21 to 30 do not.

Types 1 to 27 have been used commercially in melting brass.

Types 18 and 19 take several crucibles per furnace.

Type 28 has probably been tried experimentally.

Type 29 is in use for melting nickel and copper scrap and may have been used for brass or bronze.

Type 30 is in use for melting copper.

criticism so far offered by the friends of electric furnace lies on the score of lack of flexibility.

The following are important types of electric furnace now in use:

1. **The Baily Resistance Type.**—The heat element of this furnace consists of granular carbon placed in a silicon carbide trough. The furnaces are built in two shapes—rectangular and round. The current is led through graphite blocks into the furnace, where

it comes in contact with broken carbon resistor material, which is heated to incandescence by the passage of the current through it. In the Baily furnace stress is laid upon the quiescence of the metal during melting. It is claimed that the quality of the metal produced is better than that kept in motion while melting. The residuary material contained in the trough into which current is carried by means of two carbon electrodes, radiates the heat to the roof of the furnace, and thence down to the hearth.

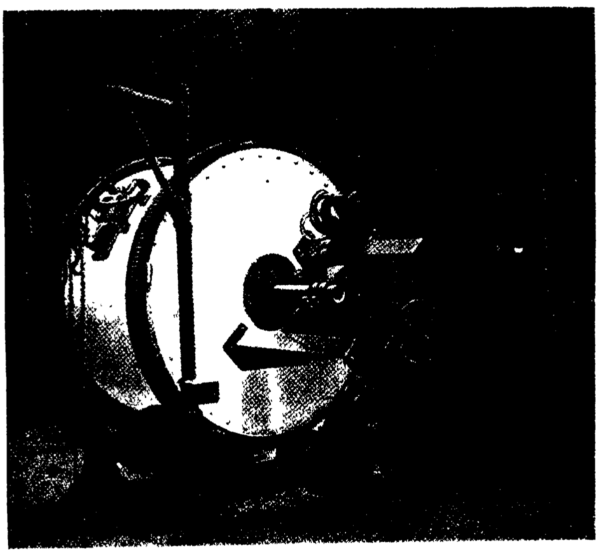

Fig. 61.—The Detroit Rocking Furnace Used by the Chase Metal Works in Melting Charges Containing Briquetted Brass Borings.

2. The Booth Electric Rotating Furnace (Arc Type).—This is one of the most recent of the types of electric furnaces. On account of the feature of complete rotation, it is claimed that this furnace is especially applicable to the melting down of borings and chips. Eight to ten heats per day are reported at an average of 550 pounds per heat. The furnace is cylindrical in shape, with doors located at the axis of the snells where the electrodes enter the furnace. The current is brought to the furnace by the moving contact method.

3. Detroit Rocking Furnace (Arc Type).—The rocking furnace consists of a steel shell properly lined, mounted on rollers and gears, which permit rocking up to 200° maximum. Heat is supplied by an electric arc between horizontal electrodes meeting in the centre of the melting chamber. The rocking is started when the metal begins to soften. Pouring is done through a spout beneath the charging door.

4. General Electric Furnace (Muffled Arc Type).—This furnace consists of a shell of steel plate, properly lined, having a bulged boiler head bottom. The roof frame hinges to a bar on a shell in front. This bar carries the support of the electrode carrying apparatus. The interior arrangement consists of three D-shaped muffles heated by the operation of vertical and cross electrodes. The space in the muffle between the electrode and wearing blocks is filled with crushed graphite to muffle the arc. The current arcs from the vertical electrodes to the graphite in the muffles, and the whole mass heats uniformly over a large area. This furnace is mounted on trunnions for pouring.

5. Rennerfeld Furnace (Arc Type).—The arc is formed between the tips of three electrodes and a mechanical force, generated in the vertical electrode, pulls the arc downward. This furnace is usually built in small sizes and has been successful in melting coin metals, bronze, brass, and bearing metals. It has been adopted as standard by the United States Mint.

6. Ajax-Wyatt Electric Furnace (Induction Type).—This furnace consists of a cylindrical top, properly lined, carrying a pouring spout. The furnace is mounted on trunnions for pouring. In this furnace a number of inductions is used to cause a continuous circulation of melted metal in the furnace. It has been used primarily in yellow brass melting. An induction coil is thrust horizontally through the lower part of the furnace; current passing through the coil is induced into the charge giving both heat and circulation.

7. Ajax-Northrup Electric Furnace (Induction Type).—This is the high frequency induction type of furnace, consisting of a melting chamber, entirely surrounded by induction coils. The lining of the chamber is arranged to be non-conducting both to thermal and electric forces. Heat induced by the high frequency current is so high that it has been possible in this furnace

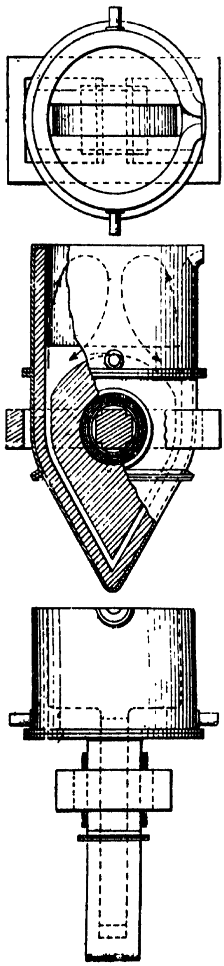

Fig. 62.—Diagram of Operation of Ajax-Wyatt Induction Furnace Used by the Ajax Metal Company.

to melt molybdenum. This furnace is used by the United States Mint.

8. Von Schlegel Furnace.—This is of the Repelling Arc Type. The furnace is mounted on trunnions for tilting and pouring. By repelling arc is meant the feature whereby a repulsion occurs forcing the electrodes apart when the current is turned on. The amount of repulsion is proportionate to the amperage. By moving adjustable weights, the amount of repulsion is varied and thus the amount of current is varied. Electrodes can be raised and lowered as a unit. The arc is very similar to that produced by a flaming arc lamp. The furnace is especially unique, in that the drawing of the arc is entirely accomplished by lateral movement.

The electrodes are approximately parallel while operating. The relative position of their ends is not affected by the wearing of the electrodes. If any influence breaks the arc, it immediately reestablishes itself.

Other electric furnaces for melting non-ferrous metals are the Snyder and the Weeks.

To summarize, the usual methods of melting consist of crucible, open-flame furnace and electric furnace. The usual practice is to add 25 per cent of borings and turnings to the regular charge, although many brass founders practice the melting of light scrap or swarf alone.

It has long been recognized that for any kind of melting, the fabricating of the loose stuff into lumps or briquettes is of benefit for the following reasons:

1. Melting losses are appreciably diminished.
2. The time of melting is much decreased.
3. The number of heats per day is therefore much increased.
4. Transportation to the furnace is facilitated.
5. Charging is much facilited.

Bundling or cabbaging—whereby long strips or sheets of metal are pressed into rectangular bundles suitable for melting—has been established practice for some time. It is a recognized economy, and bundles are quoted at an advance over loose scrap. Bundling, as such, is limited to the long flexible turnings and sheets. Nothing can be done, so far as these cabbaging operations are concerned, with the loose fine needles, the borings, the punchings and the brass washings. That is purely a function of metal briquetting.

It must be emphasized that the briquette and the bale are in no sense competitive, for the reason that they use material in absolutely different form.

Applied to crucible or furnace melting, the cause for the briquetting is easy to prove. Especially important from this angle are the economies effected, and the saving of actual melting time, prevention of vaporization and oxidation losses through the use of briquettes.

The following test is typical:

Material charged	Pounds	Test started	Crucible taken out	Melting time	Loss in melting	
					Lbs.	%
Manganese bronze chips—loose	727	1:00 P. M.	5:20 P. M.	4 hr. 20 min.	137	18.8
Manganese bronze chip briquettes	727	1:55 P. M.	5:40 P. M.	3 hr. 45 min.	62	8.5
*Manganese bronze chips—loose	727	8:30 A. M.	1:00 P. M.	4 hr. 30 min.	164	22.5

Kind of furnaces: Common crucible furnaces with natural draft.
Kind of fuel: Hard melting coke.
*Note: Some flux of unknown composition used.

It will be noted that the above test was made upon manganese bronze turnings, an all light swarf charge—and metal losses were abnormally high. Certainly in this case the prime economy realized was that in decrease of metal loss. Where (a) copper percentage is increased or (b) large proportions of heavy scrap and pig are added or (c) the electric furnace is used, the savings due to metal loss prevention become less in

evidence, and may completely disappear. None the less, in all cases, the saving of time, of fuel, of labor, combined with the increased capacity of the plant, are sufficient to justify briquetting in practically all instances.

The increased metal loss incurred in melting light scrap, as such, is due somewhat to oxidation, but mainly to the volatilization of zinc, the vastly enlarged metal surface in contact with heated oxygen giving excellent opportunity for such loss. Hence, the greater the zinc content, the greater the need for briquetting.

In the crucible and furnace melting of yellow brass, losses run about 8-15 per cent where turnings alone are melted, and about 3-5 per cent total metal loss where the charge consists of 75 per cent mixed scrap and pig, and 25 per cent of swarf. Where briquetted turnings are melted the 8-15 per cent loss above mentioned becomes 2-5 per cent—practically equivalent to the loss incident to melting yellow brass ingot, and the 3-5 per cent loss, incident to melting a mixture of 75 heavy and 25 per cent light scrap, is brought down to 1-2 per cent.[1]

Where copper content is high, prevention of metal losses by briquetting is small, but other economies are noteworthy. The following test on melting red brass chips at the Ajax Metal Company, both briquetted and loose, gives an interesting comparison:

Heat No.	1	2 Briq's	3 Briq's	4 Briq's	5 Briq's	6 Loose turn'g.	7 Loose turn'g.
Charge in lbs.	OTHER MATERIAL MOLTEN IN FIRST HEAT IN ORDER TO BRING THE FURNACE UP TO THE RIGHT TEMP	450	450	450	450	450	450
Weight of product Ingots		424	429	422	428	424	425½
Time start		7.35 A. M.	9 06 A. M.	10 10 A. M.	11.17 A. M.	12.40 P. M.	2.10 P. M.
Time finish		8 55 A. M.	10.10 A. M.	11.17 A. M.	12.25 P. M.	2 10 P. M.	3.43 P. M.
Time cons'd		80 min.	64 min.	67 min.	68 min.	90 min.	93 min.
Loss in lbs.		26	21	28	28	26	24½
Loss %		5.77	4.66	6 22	6.22	5 77	5.45
Coke lbs.		155		175		254.5	
Gain in time, over 91½ min. (st'd)		13 min.	27½ min.	24½ min	23½ min		
Coke saved, over 254 lbs (st'd)		99 lbs.		79 lbs			

[1] E. S Sperry, *Trans. Am. Inst. of Metals*, Vol. 6, p. 14, states that yellow brass chips briquetted without binder are melted with a loss of 1½ per cent to 2 per cent, whereas without briquetting the loss is at least 5 per cent.

As red brass is high in copper a saving in metal is not expected. However, there is a gain of 30 per cent in time, which of course will increase the capacity of the crucible to that extent. A five-heat-per-day crucible could thereby run six heats, with consequent economies in labor and overhead, amply sufficient to more than return the briquetting cost. Add to this a saving of over 30 per cent coke and it becomes evident that the fuel charge against the six-heat furnace on briquetted brass swarf is no more than that of the five-heat furnace operating on the loose stuff.

Crucible melters generally have recognized these economies and have been willing to pay $20.00 per ton for the cleaning and briquetting of brass swarf. In the case of higher priced alloys, as for instance Monel metal, it is becoming more frequent for melting firms to refuse the swarf at any price unless briquetted.

The Electric Furnace, which seems, in one form or another, to be rapidly displacing crucible and furnace melting in large non-ferrous metal establishments, has been able to reduce metal losses to 1 and 2 per cent, even in the case of yellow brass, and briquetting cannot be expected to improve much thereon. The evidence, though meagre, seems to show that it pays to briquette metal scrap for electric furnace melting from the standpoint of time, power, labor and electrode saving. Tests are not available on all types of furnace hereinbefore described. It is perhaps natural that advocates of electric furnace melting should hesitate about advising briquetting as a preliminary to their operation.

The following tests[1] at the Chase Metal Works covering an extended period of time form some basis for comparison:

Tonnage melted	500 tons
Average melting time per ton	51½ minutes
Average kilowatt hours per ton	224
Average net metal loss	1.02 per cent
Nature of Charge	
New copper	600 pounds
New zinc	400 pounds
Mixed, heavy scrap and briquetted borings	1,000 pounds

FURNACE USED—DETROIT ROCKING

It may be assumed that the portion of the charge designated as "mixed heavy scrap and briquetted borings" consisted of 50 per cent of each—the briquetted borings thereby constituting 25 per cent of the total charge.

[1] *Metal Industry*, April, 1920.

The Chase plant is equipped with two Ronay-Gilmore type metal briquetting presses described in Chapter II. The briquettes are 6 inches in diameter and weigh about 20 pounds each.

For comparison the following test without briquettes is offered:

Metal melted	585 tons
Melting time per ton	1 hour 1 minute
Kilowatt hours per ton	314
Gross shrinkage	0.59 per cent

Here it is presumed that the usual practice has been followed, and that 25 per cent of the total charge consists of light scrap not briquetted.

The difference in metal loss is in this case in favor of the loose turnings, but is so slight that little can be deduced therefrom. The melting time increase in the latter instance over the charge containing briquettes is 5½ minutes, or about 10 per cent—quite a respectable saving. The difference in kilowatt hours per ton is 38 or nearly 15 per cent.

In December, 1920, a test was run at the Ajax Metal Co.'s plant in Philadelphia to discover the relative melting speeds of, and recoveries from

Yellow brass briquettes (from chips).

Yellow brass chips (de-oiled in Rockwell De-oiling Furnace).

Yellow brass chips (oily).

The briquetted charges at first employed consisted of 100 per cent Ronay briquettes 6 inches in diameter, 5 inches high (appr.) weighing about twenty pounds each. The size of the briquettes seemed to bring about a condition that was a severe handicap to proper induction The furnace worked badly, at a very unsteady load, and melting was extremely slow.

The briquettes were split in half and cut lengthwise into 1-inch thicknesses, but the resulting run, while an improvement, still showed unsteady load and slow melting. The briquettes were further broken into pieces now about 8 ounces each (forty to the briquette) and, mixed with their own breakage (about 25 per cent), furnished the best run of the test. Practically 10 pounds per kilowatt hour were melted at a rate of 6.15 per kilowatt hour, a 7 per cent gain in melting time.

The de-oiled turnings gave a 1.4 per cent greater yield per kilowatt hour, which might be accounted for by the greater size of the charge.

The removal of oil from loose turnings, regardless of briquetting, is shown by the test to be of distinct value. Besides the greater return obtained by de-oiling as shown by the figures, this operation eradicates the smoke nuisance incident to melting, greatly facilitates magnetic separation of iron contamination, and contributes to cleanliness of the shop and better labor condition.

The yield in ingot of the small pieces is shown to be nearly 5 per cent greater, with an accompanying decrease of metal in the skimmings, subject to remelt.

Number of heats		Charge Pounds	Kwh. used	Size of pieces charged	Pounds melted per Kwh.	Pounds melted per minute	Remarks
				BRIQUETTED			
Run 1	1. 4	1200	140	Full size briquettes	8.57	4.94	Very unsteady load
2	3	900	100	Pcs. 1″ thick ½ circle	9.00	5.70	Unsteady load
3	6	1697	170	Pcs. 1″ thick ⅛ circle 25% loose turnings caused by breaking briquettes	9.98	6.15	Steady load
				LOOSE TURNINGS DE-OILED			
4	12	3953	390	Av. fine turnings	10.14	5.77	Steady load
				LOOSE OILY TURNINGS			
5	18	5400	580	Av. fine turnings	9.31	5.05	Steady load

		Per cent		Per cent
Run 3.	Yield ingot,	91.52	Metal in skimming	4.6
Run 4.	Yield ingot,	86.79	Metal in skimming	6.6

The obvious conclusion is that the big briquette is not suited to the Ajax-Wyatt furnace of the size used, but that de-oiling the turnings is of great value therein, and that the operation calls for a half-pound briquette or less, made of de-oiled turnings, to secure the greatest economy in melting and the cleanest shop condition.

It is only fair to assume therefore that where 25 per cent of briquettes have replaced 25 per cent of borings a very substantial saving in power and time has been realized. If 100 per cent of briquettes replaced 100 per cent of swarf under similar conditions, these savings would be that much greater.

The writer believes that these data are only indicatory, but the indications are that it would pay to briquette metal scrap for the Baily, and other furnaces, as well as the Detroit.

The Ohio Brass Company at Mansfield, Ohio, replaced their crucibles with a G. E. type, 2,000 pounds capacity furnace. No runs were made on briquettes, to the writer's knowledge, as feed mechanism was constructed to handle borings and small chips only, so that pig, heavy scrap, and briquettes were not called for in the operation. This company had been operating a small Gilmore press (Chapter II) for the manufacture of briquettes from red brass chips for crucible practice. With the displacing of the crucibles by the G. E. furnace the briquetting press was not operated further. The time and coke saving elements were well marked in the crucible operation. The metal saving, day in and day out, by the briquetting operation was reported as negligible. The economies effected by briquetting red brass are never so great as where the yellow metal is concerned.

Whether crucibles, fire, or electric furnaces are used the uniform shape of non-ferrous metal briquettes is of the same advantage as is the case with steel briquettes. In Chapter III it was shown that steel briquettes brought a premium over heavy scrap largely because the regularity of shape permitted a greater

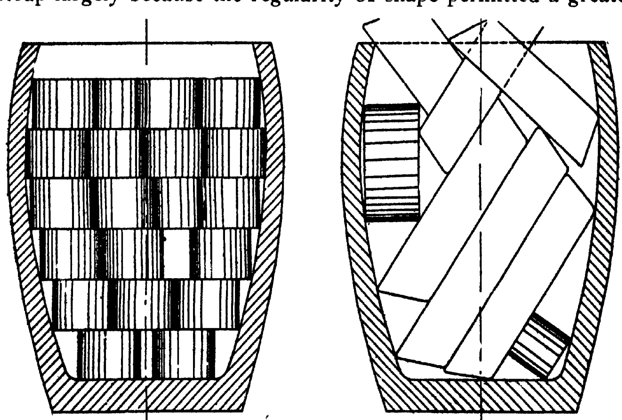

Fig. 63.—Advantages of Briquettes in Charging Crucibles. To the Left—a Briquette Charge. To the Right—a Charge of Miscellaneous Scrap. The Regular Shape of the Briquettes Permits Closer Packing and, Therefore, More Metal per Heat.

tonnage to each charging box. The same holds true of the non-ferrous metals—not as applied to charging boxes, but in the melting receptacle itself. In the above tests economies have been proven for briquetted where charges have been of equal weight.

Fig. 64.—Effect of Briquetting upon Non-ferrous Swarf. At the Right, is a Typical Pile of Brass Swarf. At the Left, an Equal Amount is piled into a Cylindrical Vessel, Representing the Packing Operation. In the Centre, an Equal Weight of Turnings Appears in Briquette Form.

Where briquettes are used the crucibles or furnace can receive a heavier charge per heat. Certainly briquetted turnings occupy less room than loose, and the regular shape of briquettes permits closer packing than can be obtained for a heterogeneous mass of heavy scrap.

Non-ferrous briquetting is carried on by certain firms, notably

the Chase Metal Works, Waterbury, Connecticut, (one Ronay and one Ronay-Gilmore press). Worthington Pump & Machinery Co., Newark, New Jersey, (one Gilmore press, used for both ferrous and non-ferrous metal briquette manufacture). American Multigraph Co., Cleveland, Ohio, (one Gilmore press). Installations have usually been made where the production of light metal swarf is adjacent to the foundry. In addition to the above,

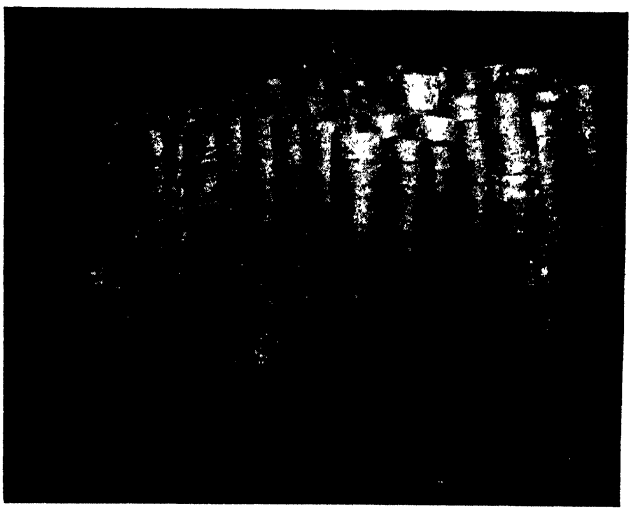

Fig. 65—Tobin Bronz Briquettes Made by Ronay Process on a Ronay-Gilmore Type of Press at the Custom Plant, New York. Briquettes are 6 Inches in Diameter and Average 4 Inches in Height.

briquetting is sometimes done on a custom basis; that is, the swarf is briquetted at a plant erected for the purpose, at so much per pound, including cleaning, and dealers in metal scrap have found such custom plants of advantage to them in increasing the intrinsic value of their product. The swarf brought to the custom plant is usually contaminated with dirt, oil, and iron particles. The service must include cleansing of these ingredients prior to briquetting. Dirt and oil militate against strength and handling quality of non-ferrous briquettes—far more so than is the case

when steel turnings are briquetted. Iron or steel contamination in brass and similar alloys must be removed practically completely. Iron, melted down in copper alloys, segregates in hard nodules, which are fatal to the edge of cutting tools. Brass briquettes containing even a minute percentage of iron are subject to rejection.

Fig. 66.—A Typical Belt Magnetic Separator for Eliminating Iron from Non-ferrous Swarf.

There are two plants known to the writer as having been engaged in the cleaning of non-ferrous scrap and making briquettes for the market in the United States: The Eastern Briquette Company of Waterbury, Conn. (Duryea press) and the Custom Plant of the General Briquetting Company (one Ronay-Gilmore press and one Gilmore press). The respective briquetting presses are described in Chapter II. The preparation methods at the latter plant comprise:

1. Disintegrating,
2. Drying,
3. Removal of iron.
4. Briquetting.

Disintegrating.—The first process is simply that of carding and cutting up the material by means of a Gilmore Shredder. (Described in Chapter III). As the metal comes to the plant in

mats and tangles it is difficult to feed to the briquetting machine. Non-ferrous metals are seldom contaminated with heavy scrap, so the blowing mechanism described in Chapter III is not used. Removal of oil, drying and softening by annealing are important,

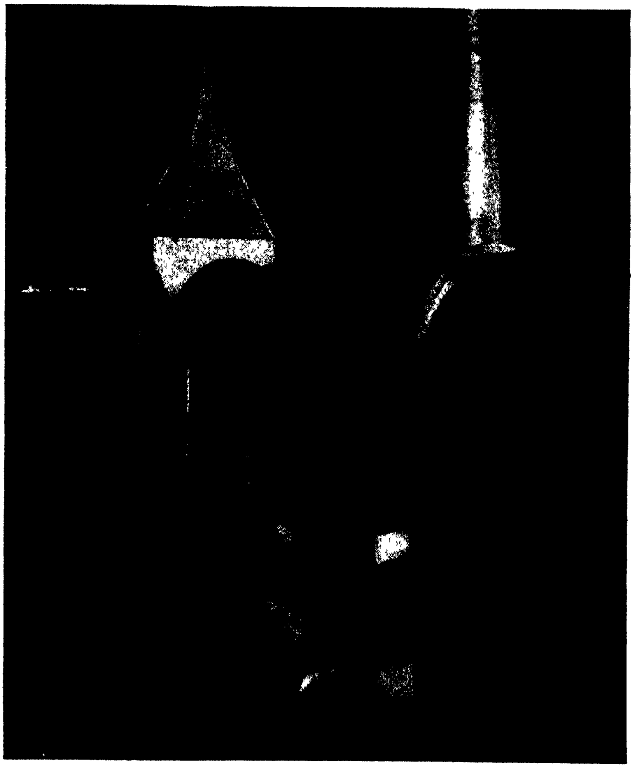

Fig. 67.—Rockwell Rotary Furnace for De-oiling Metal Swarf. Used by the Ajax Metal Company, Philadelphia.

so the material is then moved to a Rockwell rotary de-oiler, a horizontal drum about 15 feet long and 4 feet in diameter. The feed end is a little higher than the discharge end. A burner is placed at the discharge end which throws a flame into the furnace,

exhausting through a small stack. The chips are fed through a hopper. As the drum revolves at a moderate speed the metal is carried to the discharge end partly by gravity and partly by vanes inside the furnace, which are so shaped as to push the metal along in one direction. The dried chips discharge automatically through a hole in the shell, which comes into the discharge position with each revolution.

The heat has two effects on the metal. It burns off all the oil, grease and water; it anneals the metal, softening it so that it can be briquetted without having a tendency to spring back out of the briquette. It has been found that by giving the metal this preliminary heat treatment, a large part of the difficulty of forming briquettes out of elastic material is overcome.

The "flow" of non-ferrous metals, and "skin tension," that serves to lock the metal particles together, are accentuated, if anything, in the case of non-ferrous briquettes, especially when annealed.

Magnetic Separation.—From the de-oiler the metal is transferred to the magnetic separator, which is simple both in principle and in operation. The pieces run over a magnetic pulley, and loose iron is very simply and thoroughly separated.

Briquetting.—From the separator the metal is fed directly to the Ronay-Gilmore hydraulic briquetting press. The operation of this press is described in Chapter II.

It must not be supposed that the entire treatment is necessary for all metals. The full course is only prescribed for tangled turnings, full of dust, oil and iron. Oily chips, with iron contamination, omit the disintegration and begin at the drying furnace. Clean dry chips free from oil or iron, are fed directly to the briquetting press. The plant is arranged so that any one or more of the operations may be omitted.

The briquettes are hard, firm, can be thrown about and stand transportation well. They do not disintegrate, but melt down evenly, and from the outside.

Where very hard and tough metals, like nickel shot, are concerned, which are not perceptibly susceptible to softening in the annealing treatment, binding admixtures have, to a limited

extent, been employed. Sulphite liquor has been employed in the case of nickel and manganese bronze, but has proven somewhat objectionable due to a small percentage of sulphur. Milk of lime has also been used with some degree of success, but is not so strong a bond is as the sulphite liquor. The uniform policy has so far been to use no binding material unless high pressure fails absolutely. Such instances are few.

Many foundries near New York now insist that swarf sold them be briquetted. The briquettes are the usual Ronay product 6 inches in diameter, 5 inches (more or less) high, weighing about 20 pounds. The progress of non-ferrous metal briquetting has been slow of late, due to the advance of electric melting, and the lack of full knowledge of the scope and limitations of the various furnaces now being rapidly introduced. Once the advantages of briquetting are found to increase the production and facilitate handling in all classes of melting the progress of non-ferrous metal briquetting will be rapid.

The possibility of briquetting aluminum chips is very attractive. Possibly in no other metal are the economies to be realized so great. Aluminum oxidizes in the melt very easily and the greater the surface—as for instance in the case of small size chips—the greater the amount of oxide formed, the higher the waste, and the poorer the resultant metal. By briquetting, the contact of the surfaces with the air is reduced and the briquettes may be readily charged and submerged below the surface of a heel of molten metal.

E. S. Sperry, *Brass World*, Vol. 7, 1911, advocates briquetting in the following:

"In the treatment of aluminum chips this process is particularly important as this metal, more than any other commercial one, is difficult to treat in such a form. When briquetted, the melting would become a simple operation and the resulting metal would be worth using. Metal now made from aluminum chips is of the poorest quality."

E. F. Hirsch in a series of tests on aluminum reports in *Elektrotech. Ztschr.*, Vol. 35, 1914, that borings of aluminum when melted loose showed a loss of 13.8 per cent and required 50 minutes per heat; whereas, the same quantity briquetted

showed but 8.1 per cent loss and melted in 35 minutes. Again, the character of the resultant metal was much improved. A full report of this test is as follows:

Aluminum chips	Weight in kilograms	Melting time in minutes	Wgt after melt in kilograms	Melting loss Kilograms	Melting loss Per cent
Loose	14.5	50	12.5	2.0	13.8
Briquettes	14.8	35	13.6	1.2	8.1

NOTE: Two per cent aluminum chloride added to briquettes as a flux.

PHYSICAL TEST OF METAL

Kind of Bar	Chips	Chips	Briquettes	Briquettes
Elongation in mm.	0.8	0.8	1.2	1.2
Ultimate strength in kilos	2,520.0	2,120.0	2,850.0	2,800.0
Unit ultimate strength in square mm. per kilo	21.5	19.7	26.9	26.00
Per cent elongation	0.65	0.65	1.0	0.83

In *Engineering,* Vol. 94, 1912, a report is made of a comparison of tests wherein the loose borings gave but 50 per cent recovery whereas the briquetted metal showed 85 per cent.

The Bureau of Mines in *Bulletin 108*, p. 81, assumes that on account of the high cost of briquetting machinery the economies outlined above could only be obtained by very large refiners and continues to say that the process in their case at least deserves serious consideration. Since the publication of that bulletin. briquetting machinery of smaller capacity and lower price is available and, undoubtedly, within the reach of smaller refiners. It must be said, however, that no one is at present briquetting aluminum chips in the United States on a large scale. It is anticipated that the Bureau of Mines will make further experiments upon it during the coming year. On account of the lightness of this metal operating costs are high. It costs practically as much to make an aluminum briquette as one of brass so far as time, labor and overhead are concerned and the cost, therefore, would be about three times as much. Apparently, the metal saving in improved metallurgy justifies the procedure.

Briquetting has had some application in the refining of precious metals.

At the Marsac Silver Refinery in Utah briquetting of cement-silver or pressing into cakes has been in use. A hydraulic press, with mould 6 inches in diameter and 4 inches high, is used. 1,000 pounds per square inch is sufficient pressure. Pure glycerine is used in the pump-tank in place of water. The press was

made by Watson & Stillman, of New York, and works very satisfactorily. After briquetting the silver cakes are dried in a small dryer heated by air derived from the iron chimney of the muffle furnace. An air chamber is formed round the chimney by a mantle of sheet iron, and from the annular space the hot air is drawn through the drying chamber by a Koerting ventilator.

Fig. 68.—Making Non-ferrous Metal Briquettes on the Gilmore Horizontal Press.

A—Hopper. *E*—Ejection Port.
B—Plunger. *F*—Air Bottles.
C—Mold. *G*—Pump.
D—Stop Block and Stop Block Lift.

Briquettes are also made from gold precipitates at the El Oro Mine, El Oro, Mexico, for melting into bullion. The briquettes are made on an upright press run by compressed air. The briquette mold is 2⅞ inches in diameter. At 80 pounds air pressure the briquettes receive a pressure of 2,000 pounds per square inch; generally 1,000 pounds is sufficient. The precipitates are forced into the mold by a plunger feed, which is at the bottom of a V-shaped hopper. The briquette is made on the down-stroke of a plunger, and is returned to the top of the mold by a return plunger, connected to the piston-rod by side rods. Two men handle the operation, making ten briquettes a minute. The binder is 8 per cent of slacked lime, moistened by a saturated solution of borax water, and added to the flux. Where borax water is used

alone, the precipitate is first dried. With lime, the mix should contain about 10 per cent of moisture. Crude petroleum has been tried as a binder, but the contained carbon reduces zinc and other metals and produces a base bullion.

Briquettes, 3 inches thick, average 2 pounds in weight.

For melting, crucibles are used. As soon as the bottom of the crucible becomes dull red, the damp briquettes are charged. In from 60 to 90 minutes the briquettes in the bottom start to melt, and, as the charge sinks, fresh additions are made until it is impossible to add the damp briquettes except directly to the molten mass. If charging were continued too long, the charge would spit and throw the slag and metal out of the crucible. It takes from 3.5 to 4 hours to melt and pour a charge. Five furnaces at one time are used for refining precipitate.

Of interest in this connection are the experiments of F. A. Fahrenwald in making briquettes from gold filings, precipitates and colloidal mud. These briquettes were forced through small openings and the wire formed subjected to certain tests. The same procedure was gone through in the preparation of briquettes from tungsten and molybdenum. The briquettes were made on a laboratory press using the screw principle. (See reference below.)

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CHAPTER VI.

A DISCUSSION OF BINDERS.

By the term "Binder" in connection with briquetting is meant any substance that possesses cohesive or gluelike properties, and is, therefore, capable of binding fine particles one to another. In practically every instance the efficiency of binders is increased by the use of pressures; that is, the greater the pressure exerted in the briquette press, the smaller percentage of binder necessary to achieve a given result. This statement must be modified when excessive pressures are used, for, especially in the case of material fed to the press in too dry a state, such pressures cause laminations in the briquettes, or parallel lines of weakness, similar to the cleavage familiar to geologists. The percentage of binder admixture, too, can be kept at a minimum by the use of a properly designed preparatory treatment.

Few substances are capable of commercial briquetting by pressure alone. Metal swarf has already been discussed (Chapters III, IV, V). The surface of the metal, on which flow or skin tension is set up in metal chips under the high pressures involved may, in a sense, be considered the "binder" in these instances. The pressures of 20,000 to 30,000 pounds, usually realized by hydraulic means, are expensive, usually beyond commercial practicability for ores, fuels, and kindred products, and are moreover inadequate in these cases. What pressures are necessary to achieve binderless briquettes on such fine materials is not definitely known. The question is academic only, for their cost, viewed commercially, is prohibitive. Besides metal swarf, the only substance to-day briquetted commercially without binder (other than its own water of crystallization) is salt, pressed in some places into dense blocks for use in animal "licks."

In the following table binders are divided into four great classes—A, B, C, and D. (A) binders are pressed, distilled or otherwise evolved from the material to be briquetted, during the process of briquette manufacture. (B) binders require some chemical action to obtain setting action. Column 2 comprises a list of inorganic cements whose "set" calls for the addition of water. Column 3 comprises such binders as are made in the fine material by chemical action induced by a reagent

TABLE VIII.

Classification of Binders

A	B			C		D
Binders evolved from the material to be briquetted, either by a preparatory heat treatment or by the act of pressing	Bindess produced by chemical or physical action during the course of briquette manufacture, by the use of reagents, with or without treatment			Binders possessing in themselves cohesive or glue-like properties and capable of binding fine materials thereby		Binders or mixtures of binders combining properties of B. and C.
(1) Resins and gums Evolved from fine wood waste—as in the Arnold process for briquetting sawdust and wood-planings Hydrated cellulose Evolved from peat in the course of mechanical preparation, the presence of moisture and in the pressing thereof Bitumen or pitch Evolved from lignite in the German "Braunkohle" briquetting process. Tar or pitch Evolved from various coals when briquetting mold is subjected to heat during the pressing operation	(2) By hydration of an admixture of lime magnesia gypsum Portland, natural and slag cements clay The addition of water to the above materials produces a "set" capable of holding a large proportion of inert fine material in bond	(3) By catalysis, or corrosion binder being made from material to be briquetted Ferric oxide, formed in finely divided iron or ferrous oxide of iron by the addition of certain acids or salts of those acids in solution Zinc oxide, zinc chlorides, and zinc oxychlorides, formed by adding certain reagents to zinc minerals Other metallic oxides, formed by additions analagous to the two above mentioned (none commercially practised)	(4) By extraction, and mastication, binder being extracted from fuel by the admixture of a liquid capable of dissolving binding elements *out of the fuel* during a heavy masticating action	(5) *Oleaginous tars* pine wood tar hardwood tar gas tar by-product coal tar pitches from above tars. Asphalts· (*a*) natural, (*b*) petroleum residuum, water soluble asphalt binders	(6) *Water soluble* glue, starch, sulphite liquor (neutral), water glass, molasses, Above binders usually call for a carbonizing or baking treatment for the briquettes to render them waterproof	(7) In briquetting certain substances advantage is taken of the cohesive property of the binder (6) to hold the briquette together during rough handling that precedes the "set" obtained in (2) or (3) Acid sulphite liquor Acid tars Hite binder Gamble binder Ellis binder

(C) binders rely upon their own cohesion, generally without the assistance of any chemical action. Under D are listed such binders as are known to combine a primary natural cohesion with the evolution, by chemical means, of a second binding material—a binder within a binder, as it were.

An instance of Class A binder production can easily be illustrated in the laboratory with soft coal and a laboratory hand press. Fill a hollow cylindrical die with the coal, preferably heated. Insert a metal plunger over the coal, and placing the die in the press, apply the pressure up to 3,000 pounds per square inch. While the pressure is on, apply a flame so that the die and contents are heated to a point beyond the possibility of handling. Withdraw the pressure, allow the mold to cool sufficiently to handle. A briquette will be found in the mold, that, upon cooling, retains a strong coherence, quite equal to commercial soft coal briquettes. The combined heat and pressure have made available, as pitch binder, a proportion of the volatile matter of the coal.

Charles L. Wright, "Briquetting Tests on Lignite," page 38 reports a test on high volatile lignite by this method on a scale that might be called commercial. The press used was a Ladley type (Indianapolis Pressed Fuel Co.), consisting of two rolls of molds, one hundred and eight per row, arranged in a rim wheel, each mold being steam jacketed. (See Chapter II). A pressure of 5,000-6,000 pounds per square inch is attained by the plunger.

The lignite used was very high in volatile (48 per cent). It was heated to 208° by live steam before being fed to the press. The molds were heated to practically the same temperature. Excellent briquettes are reported. As temperatures increased there was a tendency of the briquettes to crack or "check."

As a matter of fact, the commercial briquetting of lignite or Braunkohle is done on much the same principle, except that the heat that contributes to the release of the native binder in the lignite is generated by friction—caused by construction of the briquette in the diminishing cross-section of the press mold (see Chapter II, Exter press and Chapter VII, Lignite). The heat generated is considerable.

Much discussion has been evoked by the fact that the "rope" presses used in Germany for the briquetting of "Braunkohle" were not always successful when various lignites found in the United States were submitted to them. The reason, therefore, was definitely settled by a series of careful tests run by the United States Bureau of Mines under the supervision of C. L. Wright.

Various lignites were tested for per cent solubility in carbon bisulphide, and were briquetted immediately thereafter in a German Exter press, as described. The results were as follows:

Sample used	Number of samples used	Average per cent of dry sample soluble in CS_2	Remarks
Pittsburgh			
No. 7 (Rockdale, Tex.)	2	1.20	No satisfactory briquettes made
No. 8 (Lytle, Tex.)	3	2.01	Satisfactory briquettes made
No. 9 (Calvert, Tex.)	4	1.24	No satisfactory briquettes made
No. 11 (Scranton, N. D.)	4	1.72	Satisfactory briquettes made
No. 13 (Lehigh, N. D.)	13	1.43	Difficult to briquette
No. 14 (Ione, Cal.)	7	7.60	Satisfactory briquettes made
No. 15 (Vanderwalker, N. D.)	2	1.08	No satisfactory briquettes made

It must not be supposed that the percentage soluble in carbon bisulphide represents the total bituminous binder present—none the less there is a definite ratio between the two quantities. It is evident from the above that lignites containing less than 1.4 per cent soluble in carbon bisulphide (dry basis) cannot be made self-binding by commercial processes—while lignites showing 1½ per cent soluble in carbon bisulphide are briquetted without difficulty. Where bitumen content is low, a higher percentage of water is necessary.

In the briquetting of wood waste the Arnold process (Chapter VII) releases the gums and bitumens from the wood, using a similar method of mold construction, but in this instance the binder release is assisted by steam, drying the wood waste prior to the press operation. The press friction alone has been found inadequate to release the natural wood binders, but preheating, carefully done, has served the purpose.

In peat natural bitumens occur, but the difficulty concerned with their release for binding lies in the high moisture percentage carried by their material. Very powerful presses can make peat briquettes easily, squeezing out excess moisture, but the cost is excessive. Peat dried in the air down to 30 per cent

moisture, approximately, and properly disintegrated has been briquetted successfully on the Universal Press (Chapter VIII). There can be no doubt but that the pressure of the rolls has helped to release a hydrated cellulose binding material as well as bitumen, from the peat cells. This binder sets hard, accompanied by marked shrinkage of the briquette, when the peat briquettes dry.

The value of the application of (B) class binders is confined to inorganic materials, broadly speaking. Applied to fuels they are subject to the disadvantage of adding ash to an extent not compensated by superior binding quality. Again, these binders give briquettes that are weak when new, strengthening gradually in proportion to the rapidity of the set. Fuel briquettes made from them have the advantage of holding together well during combustion, and are not smoky, but in nearly every case are distressingly difficult to kindle. There are as yet no commercial fuel briquetting plants in the United States using inorganic materials for binder, but many metallurgical plants both here and abroad are briquetting their ores and dusts by one or the other of these methods, with success.

Lime.—Of the chemical binders whose setting property depends upon the addition of water, lime (calcium oxide), is the most important in the commercial sense. The use of lime as a constituent in mortar, and as one of the active principles in Portland cement are familiar. The use of lime in briquetting is entirely similar. It is either used alone, or with other material, whereby a cement is made.

When water is added to calcium oxide, calcium hydroxide is formed, and, when the water is in proper proportion, forms a paste. The paste hardens in a few hours, due to the absorption of carbon dioxide, so the "set" is produced by the gradual replacement of calcium hydrate by calcium carbonate. Where silica is present, small quantities of calcium silicate are in addition formed. Calcium silicate is an exceedingly strong bond. The formation of calcium silicate by the action of lime and quartz can be hastened by treating the mixture with steam. This phenomenon is taken advantage of in the manufacture of sand lime brick, a rapidly growing industry. The bricks, after being formed in the press, are placed in a chamber, and steam under

pressure admitted. The treatment continues for several hours at the end of which time the bricks are set, and are very hard and strong. The same effect can be produced by air drying under atmospheric conditions, but a vastly longer time is required. When the silica is combined, as in the case of aluminum silicate, and also in various clays, the formation of calcium silicate proceeds more rapidly.

Lime, in common with most inorganic binders, has not been commercially used in fuel briquetting. The Bureau of Mines (*Bulletin No. 24*—"Binders for Coal Briquettes") reports complete failure to obtain a good briquette, even in the laboratory by the use of lime alone. The writer has made a fair experimental briquette of coal on a hand press (Chapter XV) by masticating the coal thoroughly with milk of lime, pressing at 6,000 pounds per square inch, leaving the die under pressure for a minute, gingerly removing the briquette from the mold, and allowing it to remain undisturbed for several days. Milk of lime has been used on a small scale in metal briquetting practice, particularly in the case of hard bronzes, not annealed, and an improvement in the bond secured, probably because the metal was attacked by the caustic and a cement thus manufactured.

Lime is used to briquette many metal ores. Its use in conjunction with the White press is typical (Chapter XII). In these cases the lime acts as mortar, binding the ore by means of calcium carbonate formation, or, by action on free or combined silica to form calcium silicate. The setting of lime is much retarded by mixing it with oil or any of the cellulose binders, so attempts to combine the initial set of the glue-like binders with the delayed set but excellent bond of the lime, have in the main proven useless.

In short, lime has proved useful in briquetting materials containing silica, and is useful as an adjunct to other binding materials, or as a constituent of cements; but there is no record of its use, alone, to bind materials chemically inert to it, on a commercial scale.

Clay.—Clay is the long known raw material for brick making. It was natural that the early efforts at briquette making should turn to clay first as binding material. Chevannes of England added clay and a host of other materials to coal slack to make

pressed coal in 1789. In 1872 L'Oiseau built the first practical fuel briquetting plant in the United States, located at Port Richmond, Pa., and clay was used as a binder. The first briquettes were weak, but a method was evolved for drying and waterproofing, and it is said that the project was a technical success, although high costs led to its abandonment.

Such investigations as have been made, together with the above examples, indicate that clay will never be used in commercial briquetting plants, as the sole admixed binder. Inventors frequently incorporate it in binding mixtures, depending upon the alumina present to react with other added ingredients to form a cement. The Bureau of Mines reports "Clay in connection with other binders may be regarded as an adulteration of doubtful value to the consumer."

In certain sections of Europe peasants still make briquettes by mixing coal and dust and clay, pressing somewhat, and sun drying. These briquettes are for home use and will not stand shipping, nor exposure to water.

Clay has proven a useful binder for iron ores where it occurs in nature mixed with the ore. At Kertsch, Russia, the "bean" ore has been mixed with 8 per cent of water and made into briquettes at 5,600 pounds pressure. At Ilsede, Germany, clay iron ore is mixed with iron scale from rolling mills. The mixture is heated to 75° C. and pressed into briquettes at 4,000 pounds per square inch. Attempts to duplicate the results at these places by adding clay to iron ore proved too expensive and in the end deleterious to the ore.

Magnesia.—The oxide of magnesium, when treated with water, sets to a harder and tougher substance than does lime, and the set is far more rapid. Consequently it is more practicable to make fuel briquettes using magnesia binder than if lime is so used. Coal briquettes have been made on a small scale using 3 to 5 per cent magnesia as binder. The briquettes are hard, but brittle, when less than 4 per cent binder were used. The magnesia binder set slowly, and the briquettes have to be dried to insure transportation resistance. They are not waterproof, but resist the destructive action of water to a degree. When 8 per cent magnesia was used the resistance to water was good but they were difficult to ignite. While coal briquettes made with

this binder were an improvement over those made with lime, the increase in ash, the high cost of the binder, and the time required for setting are sufficient to render the use of magnesia alone as a fuel briquette binder extremely unlikely. Magnesia as well as lime frequently occurs in ores and flue dusts, and undoubtedly assists the cohesion of other binders used. Such assistance is incidental and not of great importance. The high cost of the magnesia, practically prohibitive so far as fuel briquetting is concerned, precludes its adoption for ore briquetting as well.

Ludwig Weiss, of Budapest, obtained a patent March 6, 1906, for a briquette binder consisting of equal parts lime and magnesia. This binder was made from the waste of the Austro-Hungarian carbonic acid works, who used dolomite as a raw material for their product. This binder has not been introduced in the United States in any way.

Magnesia Cement.—The mixture of magnesium chloride with calcined magnesia gives a highly efficient binder known as Sorel or magnesia cement. Its use is well known in the making of high grade stucco. Dr. A. Gurlt first suggested its use in the fuel briquetting industry. There can be no doubt but that the coal briquettes so made were weather resisting, excellent in the fire, and easily transportable. But the initial expense of the cement, the necessity for drying and the additional cost thereof, has prevented the general use.

The Bureau of Mines reports increases of strength in briquetted materials by the use of magnesia cement over magnesia, but reports against the binder—for fuel purposes—on the ground of liberation of chlorine fumes in combustion, in addition to the handicaps mentioned above.

Calcium Sulphate.—This is the familiar plaster of paris, and has been recommended as a binder for briquettes. Twelve per cent admixture is said to be necessary to form a good briquette of anthracite culm. This was by laboratory methods. Probably considerably more would be necessary in roll press practice. Such a large addition—containing a percentage of sulphur—by the way—is not desirable in the briquetting of fuels, for obvious reasons, and there are few instances where other materials would not preferably be used for ores.

An interesting application of calcium sulphate to briquetting of ores for blast furnace treatment is that of Bernard T. Colley of Rancaqua, Chile, described in the *Engineering and Mining Journal*, Sept. 18, 1915, as follows:

"This process consists in taking the sulphur dioxide from the roasters for the manufacture of sulphuric acid (20 per cent or stronger). This acid is then thoroughly mixed with crushed limestone and agitated, producing calcium sulphate. This calcium sulphate to the extent of 5 per cent is then mixed with the roasted ore, where it exercises the same briquetting power that plaster of paris would."

It will be noted that 5 per cent of calcium of sulphate required for ore briquetting contrasts with 12 per cent required for coal. This is an example of a general truth—namely that the percentage of a given binder required to briquette substances varies inversely as their density.

The author has no record of the application of the Colley process in the United States.

Cements.—Under the generic term of "Cements" are grouped those mixtures of inorganic materials which, by addition of water, form in themselves a hydrated calcium silicate (Ca_3SiO_5) constituting a bond. Cements are normally grouped into three classes:

1. *Portland Cement.*—A finely pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous material. Good Portland cement is practically Ca_3SiO_5, with but little adulterant.

2. *Hydraulic (or natural) Cement.*—A finely pulverized product resulting from the calcination of an argillaceous limestone at a temperature only sufficient to drive off the carbonic acid gas. This is a cheaper product than natural cement, and correspondingly less efficient. The chief adulterant is magnesia, which, while in itself a bond, and according to Weiss (see above) a benefit to calcium oxide when added to it for bonding purposes, is apparently a detriment to the efficient setting of calcium silicate.

3. *Slag Cement.*—A product formed by the granulation of slag, drying, mixing with slacked lime, and grinding the mixture.

These cements are actually on the market under the above mentioned trade names, and very considerable research has been made in respect to their availability for briquetting purposes.

In briquetting, they are frequently manufactured in the process, a part of the cement constituent being in the material to be briquetted, so that it is necessary merely to add a missing ingredient. For instance, where argillaceous and siliceous matter is contained in an ore, the addition of lime to the mass brings about the lime silicate or cement reaction—helped by the pressure of briquette formation.

So far as fuel briquetting is concerned, Portland cement is more expensive and but little better than plaster of paris. Hydraulic cement would make a cheap binder but would have to be used in such large quantity as to be very objectionable. Slag cement is inferior to either Portland or natural cement as a binder for coal slack. Applied to the usual methods of fuel briquetting these cements are all subject to the following disabilities:

1. Too long a time is required for "set" after pressing, resulting in difficulties in handling and storage.
2. Too much ash is added to the briquette.
3. The briquettes are difficult to kindle.
4. The briquettes lack resistance to disintegration in water.

A very radical departure from the usual methods in coal briquetting is reported in the Longstreet process for agglomerating coal dust fines. The inventor has found a method for utilizing a lime silicate cement by treating it in such a way that in setting a high degree of porosity is obtained in the binder structure. As a result the briquetted material is said to kindle easily and burn well. The process consists of mixing culm with a minimum of treated cement and cold water. The mix is placed in rough plank forms several inches deep, and over a surface of several square feet, limited only by the building. A roof is called for as a protection during setting. The setting time is forty-eight hours. When sufficiently hard the mass is broken into pieces small enough to be put through a crusher, which breaks it into commercial size. The inventor claims 100 per cent combustion to this fuel, together with the advantages of smokeless and odorless burning, when used with anthracite fines. Tests with bituminous coal

have, it is said, given equal satisfaction. While at this writing no commercial plants are in operation, it is said that a prominent anthracite operator of Scranton, Pa., has secured the rights and contemplates establishing plants throughout Eastern Pennsylvania.

The mixing of Portland cement with other binding materials as magnesia, magnesia cement, resin, pyroligneous tar, coal tar, and numerous others for fuel briquetting has been made the subject of many patents, none of which are known to be of wide use to-day.

The application of cements to the briquetting of cast iron borings and other metals swarf is advocated by the Alton Process Company, of Worcester, Mass.

In the field of mineral and ore briquetting no operations are at present active using any one of the three divisions of cement as outlined, at least, to the writer's knowledge. There are many processes available, mostly in the experimental stage, by which calcium silicate or a mixture of silicates of cementing power is manufactured in the course of the mixing, briquetting and after treatment, and as such may be considered, from one point of view, as properly in the cement subdivision. However in the great majority of instances the material to be bonded contains silica or silicate, and the cement is manufactured in the process by the simple addition of lime. This has already been touched upon under the heading *Lime,* and further in the discussion in Chapter XIV. Other instances may be mentioned.

Another instance of the use of slag cement in the briquetting of iron ores and flue dust is the Scoria Process, installed about 1910 at the works of Friedrich Krupp, A. G., and at Thyssen. This process was developed by Professors Oberschulte and Mathesius. In this process granulated slag and lime are mixed with the ores and flue dust, and exposed to moderate tension steam.

The feature of steam hardening, necessitating costly equipment, considerable space, and loss of time, renders American blast furnace men skeptical in regard to the adaptability of the process to their needs.

Professor Mathesius later patented a method for briquetting iron ores and flue dusts, which consists in mixing "highly basic"

alumina silicates with ferric hydroxide in the presence of water, which might be called the Scoria improved. In this manner a binding medium is obtained consisting of complex compounds of lime, alumina, silica and ferric hydroxide. In one of the Mathesius patents (1,104,124, July 21, 1914) it is stated that the result is an iron cement, the iron acting in a manner similar to the aluminum in Portland and like cement. For the highly basic alumina-silicate, caustic lime may be used, which is stated to be the silicate required on account of the presence of alumina and silica in the limestone from which the caustic lime is made. Prof. Mathesius directs that the mixture be molded in a press, and states that setting will then take place after a few hours. Technically speaking, the use of caustic lime with alumina and silica is in effect a lime silicate reaction, and the iron cement would be formed only in the presence of FeO.

An extremely interesting cement briquetting process applied to ores in general, and iron ores in particular, is the Filter Dust Cement developed by Professor Otto Kippe, of Osnabrueck, Germany. Filter dust is a by-product of blast furnace gas cleaning—a term generally applied to the extremely fine flour obtained by dry filtration of the gas after the coarser dust has been eliminated. Prof. Kippe reports this material, in German practice, as consisting of approximately 29 per cent silica, 20 per cent alumina, 27 per cent lime, 4 per cent iron, the balance consisting of miscellaneous oxides. Owing to its finely divided condition and the composition the dust is in effect a slag cement. Professor Kippe (Patent No. 1,078,544) calls for 5-10 per cent of this dust, to be added to ores or flue dust, the material pressed into briquettes, and the briquettes subjected to a steam hardening process similar to that used in the manufacture of lime and brick.

The steam hardening process is sufficiently costly to prohibit the use of this dust cement process in connection with American blast furnace practice. Furthermore, filter dust is rare, as American blast furnaces incline to wet methods for gas cleaning. Again the filter dust obtained from the Kling Weidline filters of the United States Steel Corporation (the one prominent dry cleaning method developed in the United States) differs but little from ordinary flue dust in analysis, although flour fine in texture.

Ferric Oxide.—When we come to the binders formed in a briquetting mix by corrosion or catalysis, ferric oxide takes first rank in the order of importance to industry. So far, such ferric oxide has only been used in the briquetting of blast furnace flue dust, iron ores, and other ores and dusts, notably copper, that contain large amounts of iron oxides as well as the nobler metals.

Binder formation by catalysis in briquetting iron oxides was first discovered by Prof. Wilhelm Schumacher of Berlin. It has had a wide vogue in Europe, and latterly has received some attention from the iron and steel industry in the States, several installations having been made (Chapter XIII). In this connection Prof. Schumacher says—"The catalyzing agent itself plays no direct observable part in the chemical transformation which takes place in the flue dust, but it merely serves to evoke or bring about conditions where the flue dust will of its own constitution be brought to a condition where suitable briquetting is possible." Calcium chloride and magnesium chloride have been used successfully on a commercial scale, as catalyzers. Thus:

$$FeO + \overset{\text{Catalytic}}{MgCl_2} + 2H_2O = Fe(OH)_2 + 2H + \overset{\text{Catalytic}}{MgCl_2}$$

$$Fe(OH)_2 + H_2O + \overset{\text{Catalytic}}{MgCl_2} = Fe(OH)_2 + H + \overset{\text{Catalytic}}{MgCl_2}$$

$$2Fe(OH)_3 + \text{heat} = Fe_2O_3 + 3H_2O$$

cf. "The Schumacher Briquetting Process," Joseph W. Richards, *Trans. A. I. M. E.*, Vol. XLIII, p. 392.

The term "corrosion" is used in a broad sense, signifying an addition or admixture to a moistened mass, which addition causes an oxidizing action to set in. Many salts, solutions or acids, acting upon the lower order of oxides of iron, produce a chemical action that results in the formation of higher or ferric hydroxide. Ferric hydroxide in drying out under the heat of the chemical reaction sets in a hard, hornlike mass, of excellent cohesive and waterproof qualities. The reagents that may be employed for the making of ferric oxide under these conditions are the chlorides, sulphates, or sulphites of metals (with the exception of sodium, potassium and ammonium) and their corresponding acids. The

salt usually employed in the ore and flue dust briquetting plants of this type, in the United States, is ferrous sulphate.

One part crystalline ferrous sulphate, nine parts water, and ninety parts blast furnace flue dust, which contains a preponderance of ferrous oxide, is a typical briquetting mix. These ingredients are thoroughly mixed, kneaded and pressed—the pressing occurring while the material is hot from the chemical reaction. (See Chapter XIII). When the briquette is complete the crust of ferrous sulphate may be found therein. The equations involved would be represented thus:

$$FeO + FeSO_4 + 4H_2O = H_2SO_4 + 2Fe(OH)_2 + 2H$$
$$Fe(OH)_2 + H_2O + heat = Fe(OH)_3 + H$$
$$2Fe(OH)_3 + heat = \overset{\text{Binder}}{Fe_2O_3} + H_2O \text{ (vapor)}$$

As the heat lessens and the bulk of the water passes off the ferrous sulphate is again formed.

$$H_2SO_4 + FeO = Fe(OH)_2 + FeSO_4.$$

It may be said that the oxidation takes place through acid reaction of the base reacting upon the iron ore, and returning to its own constituency after the exhaustion and drying out of the water present.

The iron oxide formed in this manner is a dense, hard, waterproof binder, and the process, as a result, is commercially in the lead, so far as the briquetting of iron oxides is concerned. Thirty per cent flue dust, if containing 45 per cent or more Fe, by the corrosion method, can be briquetted with 70 per cent inert ores, such as hematite.

ZINC HYDROXIDE AND ZINC CHLORIDE

Zinc hydroxide and zinc chloride are cements formed by a similar process, the invention of Professor Otto Kippe, of Osnabrueck, Germany. In this process a soluble salt, such as the chloride or sulphide or sulphate of magnesium, iron, etc., or the acid thereof is added to moistened zinciferous material, such as finely divided zinc dust or zinc ore. In the manufacture of zinc briquettes it is usual to incorporate finely divided carbon in the mix to assist subsequent reduction.

The zinciferous material to which the salt has been added becomes in effect the binding material for the zinc ore. The action is accounted for by Professor Kippe on the ground that part of

the zinc present is transformed into zinc hydroxide which intimately cements the substances to be bound together.

Where the reagent is a chloride, it may be presumed that a part of the chlorine goes directly to form zinc chloride, an excellent cement in itself.

An adaptation of the catalytic method of zinc ore briquetting is the Brooks method, now in use by the New Jersey Zinc Company, Mineral Point Plant, Depue, Ill.

In the Brooks method, a portion of the ore (20 per cent) is pulverized to a fineness approaching that of commercial zinc oxide, and enough salt water added (NaCl) to make a plastic mass. The percentage of sodium chloride is given as one-half of 1 per cent. Fine coal is also incorporated in the briquettes, to assist in the reduction.

After the briquettes are pressed, the salt is carried by the water to the surface of the briquette, where it segregates during the drying. Reacting with the zinc ore, especially the 20 per cent of fine material specified, it forms a zinc chloride cement. The result is a hard, cemented outside shell of ore held by the crust of zinc and sodium chlorides.

The use of this briquette at Depue gives 20 per cent greater capacity to each retort. The recovery of zinc is higher and there is a minimum of "blue billy" formed.

There are doubtless many other instances, most of them yet to be discovered, where briquetting of materials will be accomplished by the evolution of a cement from the materials to be briquetted, through a chemical action. It is a matter worthy of research.

EXTRACTED BINDERS

As stated in column B 4, p. 129, binding material may be dissolved out of the material to be briquetted by the use of suitable solvents. For instance, carbon bisulphide acting upon carbonaceous matter extracts bitumen therefrom. If a solution of the bitumen in the carbon bisulphide be intimately mixed and thoroughly masticated with the dust from which the bitumen was extracted, an excellent briquette can be made from the mixture. The carbon bisulphide, evaporates rapidly during the mixing and mastication leaving the bitumen in the right physical condition to obtain the highest efficiency from the briquetting operation. Obviously this is a laboratory matter, the cost of the reagents in-

volved being far too great for binder extraction of this nature on a commercial scale.

However, extraction of binder from carbonaceous matter by solvent action does occur—even in commercial fuel briquetting—and though it may be considered incidental, it is none the less important. Where mastication is employed for fuel briquetting, as in the Basenau process (Chapter X), the heavy kneading action of the rolls aids the added binder, often a liquid oil, to extract pitch or bitumen from the solid carbon fines. The softer the coal and the longer and heavier the mastication—the greater the amount of bitumen so extracted, and the firmer and stronger the briquettes.

As an instance, kerosene was added (about 9 per cent by weight) to a medium volatile coal, and the mixture masticated in a light edge mill for a period of fifteen minutes. At the end of that period the ground mix went to the briquetting press, and very fair briquettes were produced. Certainly they were not held together by kerosene. Extracted material formed the binder.

At the briquetting plant of the Berwind Fuel Company at Superior, Wisconsin, Pocahontas slack is briquetted under the Basenau process (otherwise known as the Dutch process) involving the principle of mastication. The binder used is known to the trade as asphalt pitch, of about 160° melting point. The amount of binder required to secure good briquettes at this plant is much less than at others where the same binder is used, without masticating. Why? Because by mastication the melted asphalt pitch has itself become an extracting agent, and has added to its binding power by drawing on the coal for additional bitumen.

Class C.—*Binders that possess in themselves cohesive or glue-like properties and capable of binding fine materials thereby.*

The above class includes practically all the organic binding materials. In fact the only inorganic binder herein classed is sodium silicate.

This Class C is divided into oleaginous or insoluble, and water soluble binders. The insoluble binders may be classed into tars, oils and pitches.

Tars and pitches are subdivided into (1) wood products—wood tar, resin, wood pitch. (2) Coal products—coal tar, coal tar pitch. (3) Petroleum products—oils, oil pitch (asphalt). (4) Gas products—gas tar.

In general, these tars, oils and pitches are only useful in fuel briquetting. There has been little success in making metallurgical briquettes with such binders. Briquetting of ores and concentrates is usually a preliminary to smelting with blast. In blast furnaces there is a period of increasing heat. The inorganic binders and the soluble organic binders ordinarily harden in that zone, benefitting the briquettes, which grow stronger as they descend to the melting zone. The oils, tar and pitches, on the contrary, soften and melt in the zone of warmth, causing a distortion of the individual briquettes, and a coagulation of the briquetted mass. The briquettes spread out under the load, and if present in large quantity form a tarry stratum in the furnace, throttling the blast and "sticking up" the operation.* A series of tests run on South American tin ore, briquetted with asphalt binder, showed a marked slowing up of the melt, due to the softening of the binder, through warmth and overload. In fuel briquette combustion, where the heat zone is reached almost at once, and that without overload, the binding material is coked under proper conditions and the binder coke holds the briquette together until it is consumed.

Wood Tars and Pitches.—In the various processes of wood distillation various oils and tars are extracted, depending on the wood used and the distillation methods. Pine products differ radically from hard wood products. The pine tars and pitches are classed as "Naval Stores" and answer a demand that puts their price, in general, beyond the price of any coal briquetting operation. It is possible that pine chips and sawdust may be carbonized at some point analagous to the West Virginia Waste Wood Company's hard wood distillation plant (Chapter VII) and in that case the tars would undoubtedly be used for charcoal briquetting.

All wood tars and pitches, viewed as briquette binders have certain points in common:

*If tar acids are present in the binder and blast furnace flue dust is the material, a corrosive action occurs as before described. An iron cement is formed, and the briquettes are suitable for the blast furnace.

(a) The briquettes, if uncarbonized or baked to remove the lighter hydrocarbons, are smoky, and the smoke is vile smelling and full of acid.

(b) The briquettes, if carbonized, and if sufficient of the tar or pitch has been admixed, are excellent. The charcoal residual from wood tars and pitches is an excellent bond.

(c) The price of all tarry wood products is out of reach of the usual coal briquetting plant, and the cost of carbonization (necessary to yield a good, odorless, smokeless briquette) makes it practically prohibitive, except for charcoal briquetting.

When liquid wood tars are used, the briquettes, as they come from the press, are soggy and weak, especially in roll press practice—and roll press practice is usual with this class of binders. This condition is improved by mastication—the more mastication the better. If the weak briquettes are exposed to the air they gradually harden, due to the evaporation of the lighter elements of the tar, and if left to themselves, will gradually become strong enough to handle and ship. Such briquettes give an excellent heat, and hold well together in the fire, even if made from anthracite. Prolonged mastication before the molding will go far toward shortening this "setting" period. However, no treatment can make a commercial briquette of coal with wood tar binder for domestic use, except carbonizing. As is the case with its near relative, sulphite liquor, wood tar is best carbonized (in the briquette) by a treatment for about 20 minutes at 600° F. (2-ounce briquettes).

The behavior of wood tar pitch is much the same as that of coal tar pitch, so far as the mechanical problems are concerned. Wood pitch, well mixed and masticated with the fine material, fluxes well, and the briquettes are sound as they come from the press. The differences between wood pitch and coal pitch lie in the after treatment, if any, and the combustion. Briefly, the odors and acid smoke from wood binders are more obnoxious than those of the coal tars; but, if an after treatment, carbonizing or distilling, be used, wood tar carbonizes and becomes a coked binder at a far lower temperature than does the coal product.

In the field of charcoal briquette making, the question of preference as between wood tar and wood tar pitch is, as yet, still

open, and the choice would depend upon the character of briquette desired. Charcoal, because of its spongy, porous nature, required large percentages of binder—30 per cent wood tar is about right. Somewhat less pitch will suffice. If the briquettes are to be used for smelting, where the wood tar smoke gives little rise to objections, it is probable that the wood pitch binder would give the cheaper product. If, however, the briquettes are wanted for cooking or other domestic consumption, then the procedure would be to briquette with the liquid tar, which permeates easily through the cellular charcoal structure, distill the briquettes, and win back, by secondary distillation, the lighter fractions of the original tar (Chapter VII).

To sum up, the wood tar and pitches can, by the use of after treatment—carbonization or distillation—make excellent briquettes when mixed with any carbonaceous fuel—the high cost of operation has confined their commercial application to charcoal only. To the manufacture of charcoal briquettes they are admirably adapted—by juxtaposition of origin, by effectiveness of bond, and excellence of product.

Resin.—Has frequently been used in briquetting of fuels, and is mentioned in patents that cover all kinds of briquetting. Resin, used as sole binding material, makes brittle briquettes and is high in cost. Used as a water-proofing agent for soluble binders, or as a stiffener of too liquid oils, it may be of use, and has shown signs of such value in experiment, but it is not recorded that it is used either alone or in mixtures in any commercial briquetting plant in the United States. Franke—"Handbook of Briquetting" records that resin showed very little strength in the briquette. It burned more rapidly than the coal, puffing and breaking the briquette with a bursting action. However, because of its high binding efficiency in the coal briquette prior to combustion, it has been used from time to time as an adulterant to coal tar pitch binder, when pitch prices were high. One per cent resin to 4 per cent pitch was reported as making good briquettes, at a saving of over 7 per cent pitch under these circumstances. But it was found when the pitch price was lowered the use of resin ceased.

Coal Products.—The coal products associated with the briquetting industry, are coal tar and coal tar pitch. Their use has been heretofore confined to fuel briquetting and is likely to remain so. Tars, as they become less liquid, and heavier, approach the character of pitches. In general, there is some haziness as to the point where tar ceases to be tar, and becomes pitch. In briquetting practice a very sharp distinction is to be made. By tar is meant such coal distillate that, when used as briquette binder, is admixed in a liquid state, either melted or flowing at ordinary temperatures. By pitch is meant such a distillate from which tar oils have been removed by refining, so that the pitch is ground or cracked and mixed with the coal in fine solid particles, being softened after such admixture by a heat treatment.

Coal tar in general is a product of coal distillation, a process more widely known as by-product coking. Strictly speaking, gas tars are coal products as well, as illuminating and producer gases are derived from coal. There is some difference in the briquetting behavior between the gas tar and coal tar.

Liquid coal tar has been used in briquetting fuels to a very limited extent. Like all other tars, it is too liquid to give a good bond, except under special conditions. One known specific condition whereby such coal tar can be used in briquetting is in combination with soft coal and with mastication. Under a heavy grinding masticating action the lighter tar oils bring binding elements of the coal itself into play, as already explained. With anthracites such action is commercially unfeasible, and even with mastication, it has been found preferable to use the heavier grade of tar.

Without mastication, none of the oils distilled off under 270° C. are useful in briquetting fuels. The melting or flowing point of a tar subjected to this treatment is 160°. Having a tar of 160° melting point, a further desideratum is a high per cent of extraction with carbon bisulphide. This applies as well to pitches. In both cases the carbon remaining after carbon disulphide extraction should be determined. Let us call this C_r or residual carbon. It is a detriment and of no value in binding. At the same time, a sample of the tar should be coked, and the percentage of residual carbon, thus available, determined. Let us call such carbon C_c.

Then $C_c - C_r$ = percentage of the tar available as binder under heat after the liquid hydrocarbons have been distilled from the briquettes. This quantity $C_c - C_r$ is of extreme importance for it represents the ultimate bond of the binding material. Its importance is not confined to the tars and pitches alone, but to all combustible binders in the entire briquetting field. Briquettes are consumed almost invariably by a heating process. It is the function of the binding material to hold, throughout the destructive process, whether it be melting or smelting, the particles of fine material. This "holding" in a heat zone depends upon the amount and physical character of the solid residual in the binder after the volatile constituents are distilled off.

The wood products, tars, sulphite liquors and the like so distilled yield a residual *charcoal*, $C_c - C_r$, fibrous in texture and extremely strong. The coal tars and pitches yield coke, and the residual coke forms the final bond. In mixed binders there may be some inorganic material assisting the bond, but a charcoal or a coke are the common thing in ordinary practice. In fuel briquetting the aim is to secure this coke or charcoal in form and quantity sufficient to ensure the continued adhesion of the fuel particles through the period of combustion. This the binder is not always successful in doing, for with certain binding materials, the residual charcoal or coke is consumed or destroyed prior to the complete combustion of the briquette. The result is a bed of red hot carbonaceous particles on the grates, shutting off the draft. Further a large portion of unconsumed carbon will be found in the ash.

Where baking or carbonization is employed after the pressing operation in briquette manufacture, the binding strength of the residual carbon is of even greater importance. Such processes are usually confined to the wood products and soluble binders, where comparatively low temperatures suffice to produce a solid bond. By baking is meant a heating process at temperatures so low that there is simply a solid, dry cellulose bond produced. By carbonization is meant a similar heating process a temperature high enough to coke or carbonize the binder, the bond then being the charcoal or coke. When these processes are employed the residual solid must hold the briquettes together not only through the com-

bustion or smelting process, but also through the transportation and shipping periods prior to consumption.

Hence in all such binders it is vital to determine the amount of carbon or other residuum available *as binder* after the liquid and gaseous elements have passed off.

Briquettes made with coal or oil products binders are seldom carbonized prior to marketing. The residual binder carbon (C_c — C_r) in heavy coal tars and pitches is high, often as high as 50 per cent against 30 per cent for asphalt, and 35 per cent for sulphite liquors. The temperature required to remove all the volatile elements is high, nearly 2,000° F., and where employed all the volatile elements of the coal are removed as well. The writer is cognizant of but one successful instance of carbonizing pitch briquettes.

The majority of coal briquetting plants have used heavy coal tar or coal pitch binders. They have the advantage of strong bond and comparative cheapness. On the other hand, the combustion of fuel briquettes using these binders is accompanied by the generation of heavy smoke, bad odors, and acid vapors. The use of anthracite briquettes, bonded by heavy coal tar, was abandoned on one of the American railroads because the tarry acids were claimed to have caused vexatious skin eruptions on members of the train crew. The briquettes, in general, show considerable degradation in handling and shipping owing to the brittleness of the pitch, resulting in surface erosion—though there is little complete breakage.

In Europe the use of this class of binder for fuel briquetting purposes is practically universal. People accustomed to domestic heating with bituminous coal have little objection to the smoke and odor generated by coal tar and coal tar pitch combustion. For the same reason there is little complaint against these binders in the western states or in Central America, South America and western Canada. On the eastern seaboard of the United States, notwithstanding the fact that coal tar or coal tar pitch briquettes are excellent, so far as preserving their integrity in the combustion zone is concerned, the smoke and odor nuisance is fatal to commercial success. The great majority of briquetting plants throughout this area have abandoned the coal tars and coal tar pitches as binders.

The use of coal tar, especially the heavy coal tar, is preferred to coal tar pitch in the United States and continental Europe. The use of coal tar pitch, involving the "cracking" or grinding of the pitch followed by a mixing of fine ground pitch and coal, with subsequent heating and briquetting, is almost universal in Great Britain. (See Chapter X).

In the world field, coal tar and coal tar pitch will probably continue for many years to come as the chief binding material for fuel, regardless of their disabilities. They are, as has been pointed out, not suited to the briquetting of ores and flue dusts, on account of softening and "running" of the briquettes under the heat and the loads imposed in the upper areas of the smelting furnace.

Gas tar and gas tar pitch are often mentioned as possible briquette binders. Formerly most of the coal tar produced was the by-product of the illuminating gas industry. To-day the term *coal tar* refers to the crude liquid produced in by-products coke manufacture, and such is assumed to be the meaning of the term in this text.

Producer gas tar, and, inferentially, its residual pitch have been shown to be at least equal to coal tar pitch in binding efficiency. It is, in effect, a coal tar made at low temperature conditions that give little free carbon in the distillate. However, the matter of producer gas tar is not at present of moment, as it is not found in sufficient abundance to enter the briquetting binder field seriously. Where it has been used it has been sold as coal tar—or, if the residuum were used—as coal tar pitch.

Furnace gas tar is the coal distillate that lines the flues of metallurgical furnaces using soft coal fuel. Both the tar and the pitch derived therefrom are subject to disabilities as briquette binders. In addition to the odor and smoke that characterize all uncarbonized briquettes, bonded with coal tar and pitches, the blast furnace gas tar or pitch briquette does not stand up in the fire. This class of tar and pitch puffs when coked, indicating the absorption of furnace gases after deposition in the flues. This puffing action rends the briquette in the fire. However, the use of soft coal for smelting is not common in American metallurgical practice, and the question is entirely European so far.

Illuminating Gas Tars and Pitches.—In this class are two radically different products: (a) Coal gas tar and pitch. (b) Water gas tar and pitch—otherwise known as oil tar and oil tar pitch.

(a) *Coal gas tar and pitch.* The manufacture of coal gas is basically the same as the manufacture of by-product coke, except that in gas manufacture the temperatures at which the tar is made are higher. This means that the free carbon (C_r) in this tar is higher than in the case of by-product tars, sometimes running higher than 30 per cent. The latter figure is unusual. The Bureau of Mines in using heavy gas and coal tars in Illinois coals, briquetting with a hand press, found that a given Illinois coal sample briquetted well with 6 per cent addition of Semet-Solvay by-product heavy tar, but that 7-8 per cent was required of heavy gas tar to accomplish the same result.

Presumably gas tar pitch was used as the binder in the briquetting plant established by the United Gas Improvement Co. Here the waste coke braize was utilized, being briquetted with an admixture of anthracite culm (3 parts anthracite—2 parts coke), the bond being furnished by 7 per cent of the heavy binder. These briquettes were used to form the incandescent fuel bed over which steam was passed for the manufacture of water gas. The binder here used was solid at ordinary temperatures and was passed through a "cracker" before melting. Whether this binder was a gas or coal pitch purchased outside or was the oil product hereinafter described is not known to the writer.

(b) *Water gas tar* and *water gas tar pitch* (oil tar and oil tar pitch).

This tar series, the product of the water gas manufacturing industry, is different in character from the tars produced from coal distillation. Crude water gas tar is a thin, oily liquid, having a specific gravity of 1 to 1.10. Water gas tar is essentially an oil product, being a mixture of unsaturated ring compounds produced by the enrichment of water gas by carburetting, or addition of oil vapors. It carries considerable water, which must be removed before the tar can be used for briquetting.

This tar has been of little value. Valuable research to the end that it be rendered valuable for briquetting purposes has been made by Robert A. Carter, Jr., Engineer with the Consoli-

dated Gas Co., of New York. Mr. Carter found that fuel briquettes could be made with 8-10 per cent of the purified oil tar and 5 per cent of the oil tar pitch. In both cases the smoke and odor nuisance was such as to practically prohibit the possibility of selling the briquettes, at least for domestic consumption in cities. The writer believes that this nuisance is present in gas products to a greater degree than in the by-product coal tars. Mr. Carter obviated this difficulty by subjecting the briquettes to a carbonization process, whereby the nuisance causing volatile gases are driven off. The result is a smokeless and, it is claimed, an excellent briquette. The residual carbon (C_c—C_r) will be the binder when the briquette reaches market. The per cent of free carbon is very small in these oil tars.

The high temperatures necessary to drive from oil tars and pitches the smoke and odor characteristic of them are reached economically by Mr. Carter's design of carbonizer, by burning the gases distilled from the briquettes themselves.

The results of this research have so far not been commercialized.

Petroleum Products.—The use of petroleum products in briquetting has made a very considerable progress in the last decade—particularly in the Eastern Seaboard of the United States. In nearly every other part of the globe, at least where a winter season calls for a artificial heat, the high prices of the petroleum products have militated against their adoption.

It has been said that, where mastication can be practiced intensely, briquettes can be made of soft coal, and any oil, even kerosene. However, these light petroleum products are not strictly binders, nor has their use been commercialized in America. They are extractors and dissolve a binder out of the coal. Strictly speaking, all the oil binders, that are available for briquetting, which in themselves contain the elements of "set" and cohesion, are, in whole or in part, *Asphalts.*

A good grade of asphaltic binder has certain advantages not even approached by other binding materials. The toughest briquette, the one best adapted to handling and enduring rough treatment, the least subject to abrasion, the highest in skin ten-

sion, is the one where the asphalt has been properly compounded and masticated with the coal prior to pressing. There is no free carbon to speak of, the usual solubility in carbon bisulphide being between 98 and 99. On the other hand, the residual coke is low, about 30 per cent, and asphalt briquettes do not hold together in the fire as well as the coal tar variety. It is usually sufficiently cheap in price to make the manufacture of briquettes profitable. The briquettes are not brittle, even when high melting points are used. The weather resisting qualities are excellent. The briquettes actually stand weathering rather better than coal. The gases of combustion are not corrosive, and there is little soot. There is light smoke, not heavy and black as comes from the creosotes in coal tar.

Still the asphalt fuel briquette contains some smoke and there have been objections on that account. None the less, the advantages are so pronounced that to-day the bulk of the briquette tonnage manufactured in the United States is made with asphalt binder.

The asphalts, or binding oils, are divided as follows:

Natural asphalts	Maltha Trinidad and Bermuda Grahamite Gilsonite
Petroleum residuums	(a) Steam-blown residuum (b) Air-blown residuum Westrumite and other soluble asphalts

The natural asphalts have not appeared to any great extent in commercial briquetting. The price in most cases is too high. The high price is due to the distance of their deposits from the briquetting points.

Maltha occurs in small deposits in the south west.

Grahamite occurs in Oklahoma.

Gilsonite is said to be in extensive quantity in Utah.

The natural asphalts—Bermuda, Trinidad, etc., are from liquids in the Caribbean.

Briquetting experiments upon these four classes of binder were conducted in 1904 by Dr. Joseph H. Pratt of the University of North Carolina. Results were as follows:

Maltha.—Is a very viscous native bitumen, rather more liquid than the usual native asphalt, but having a tendency to harden rapidly when exposed to the air. The flowing point of the sample tested was 58° C. The briquettes made of Illinois coal on the hand press were good with 3½ per cent binder, so far as their external condition was concerned, but in the fire success was only had when coking coals were used.

Grahamite.—Grahamite is a pure solid native bitumen, which does not melt readily, but intumesces at high temperatures. It was tested by Dr. Pratt as a binder for dry California lignite. The quantity required was found to be between 20 and 30 per cent, which was considered prohibitive.

Gilsonite.—Gilsonite is a very pure solid bitumen, rather more brittle than asphalt, and having a higher melting point. It has been found useful for the re-enforcing of air-blown oils. This quality will probably cause a demand at a price that briquetting cannot reach. Dr. Pratt found that the finely parted material mixed with coal dry and heated above 100° C. gave a good briquette. Four per cent was used in the hand press. The behavior in the fire was good.

BERMUDA AND TRINIDAD ASPHALTS

The natural asphalts gave a good briquette with a 6 per cent admixture. Illinois coals were used. It was said, however, that all tests with this asphalt yielded briquettes that could not compare with those made with pitch binders.

Asphaltic Petroleum Residuum.—These are heavy viscous residues, produced by the evaporation or distillation of petroleum until all the burning oils and even some of the heavier distillates have been removed. Practically all the asphaltic binders used in commercial briquetting are of this nature. There are three main varieties:

(a) Residuum produced directly from retorts.
(b) Steam-blown petroleum asphalt.
(c) Air-blown petroleum asphalt.

In the latter two grades the blowing is a cleansing process. The air blown variety is an expensive product often used as a rubber substitute, on account of its elasticity. It is quite beyond the price possibility of a briquetting operation.

The steam blown asphalt supplied by the Standard Oil and other oil companies makes a good briquette binder, provided the melting point is high enough. The majority of the briquette companies use a petroleum asphalt residuum, known as hydrolene, produced by the Sun Company from Texas crudes or an equivalent product such as is produced by the Texas Co. and the Atlantic Refining Co. This product claims recognition especially because of its freedom from sulphur and paraffin. It shares with other asphalts a good cementing strength, water resistance and toughness. Such a product is used as a briquette binder now at the

Fig. 69.—Storage Tanks for Asphaltum Residuum Binder—Nukol Fuel Company, Ltd., Toronto, Canada.

plants of the Lehigh Coal and Navigation Co., the Berwind Fuel Company, Stott Briquette Company and others. In the use of this binder a great improvement in the briquette is noticed, through the use of water, especially in the form of steam during the mixing operation. Owing to the fact that the $C_c - C_r$ content in this binder is low, the behavior of the briquettes in the fire is sometimes subject to criticism. This situation can be overcome and has been overcome in the past by the addition in the briquette of a small percentage of coking coal. There is no record of a commercial plant wherein the briquettes made with this binder are carbonized.

Water-Soluble Asphalt Binders.—There has been sustained effort to adopt water-soluble asphalts to briquetting. Asphalt can be made soluble by treating with strong alkali solution like sodium hydroxide, or ammonia water. Such a binder has the advantage of being liquid at atmospheric temperatures, thereby simplifying the mixing of the briquetting flux and eliminating the melting of the asphalt. In the briquetting a long exposure to air results in a drying out, accompanied by evaporation or chemical change of the alkali, and a return of the asphalt to the insoluble con-

Fig. 70.—Asphaltic Binder in Tank Cars Entering Melting Shed, Where it is Pumped into Storage. Lehigh Coal and Navigation Company, Lansford, Pa.

dition. In practice it is usual to give the briquette a heat treatment to hasten that action. It is, therefore, to be seen that the use of water-soluble asphalts involves a baking process similar to the baking and carbonizing involved in the starch and similar vegetable binders.

The briquetting plant of W. D. Althouse & Co., Piedmont, West Virginia, operated for some time, using a water-soluble asphalt binder, patented and furnished under the trade name of *Westrumite*. To make westrumite, certain oils and rosins were added to asphalt and the mix was treated with an ammonia solution rendering it water soluble. It is understood the plant operat-

ing under these conditions was a complete success technically; for other reasons the plant is not now operating.

WATER-SOLUBLE BINDERS.

Glue.—Various kinds of glue have been used as briquette binder, and for them it can be said that the cohesion is highly efficient. On the other hand, the expense is too great to justify the use of glues in commercial briquetting plants of any sort. Very primitive briquetting is still done where coal is scarce, and coal fines available, by hand mixing the coal fines with such glue as may be available, and stamping the mix into molds. Such primitive devices as flower pots have been used as molds. Quite a little of such home made briquetting was done during the big coal strike in England recently.

Starch.—$C_6H_{10}O_5$. Starch is a carbo-hydrate, found in wheat, corn, rice, potatoes and other grades of vegetables. It has the property of forming a jelly or paste when heated with water. Briquetting with starch involves the chemical change of the starch into dextrin. There have been many attempts to make briquettes by the use of starch binder with coal. The advantages of starch are its cheapness and its wide distribution, together with the fact that the briquettes made thereby are smokeless, and the coke formed from the starch during combustion holds fuel briquettes well together in the fire. On the other hand, starch briquettes do not immediately harden as they come from the press, and they will not stand exposure to the weather unless water proofed. Water-proofing can be done either by carbonizing the briquettes by heat, or by adding oil or tar in small proportions whereby the starch granules are coated with oleaginous material and rendered water proof, or both methods may be combined. There have been no briquetting plants operated successfully with the starch binder alone. The water-proofing of starch binder with oil has been very carefully studied. (See Hite Binder, p. 163).

Flour and Gluten.—These substances have been used to a limited extent as binding material in briquetting, but never on a large scale. They are very efficient from the standpoint of cohesiveness, but require carbonizing to render the briquettes water proof and, under ordinary circumstances, the prices are too high to attempt their use. Professor Darling in his lignite briquetting

investigation often used 2 per cent flour added to various tars to assist the binding of the lignite char briquettes. (See Chapter IX). This was based upon the fact that wheat is at its cheapest in the vicinity of the western lignite fields, particularly in the Dakotas.

Sodium Silicate.—Commonly called water glass—has frequently been suggested as a briquette binder. Mr. G. J. Mashek in his catalogue of briquette machinery recommends sodium silicate for mineral briquetting, in cases where the metallurgical requirements would permit its use. Certainly where a calcareous gangue is concerned such a binder would be effective and chemical action would make it water proof. However, it is expensive, and, so far as known, has not received a wide recognition in the mineral field. Water glass has been tried very often in fuel briquetting. The practice has been to dissolve the requisite amount in hot water and mix the solution with the coal, pressing the mix into briquettes. The briquettes so made are brittle, but of very good appearance. The main defect lies in the fact that the addition of sodium silicate to the mix lowers the fusion point of coal ash. The result is that briquettes made this way can no longer claim to be clinkerless; in fact they are very prone to clinker badly; and as a result a low burning efficiency is obtained. In addition the sodium silicate briquettes are not water proof, although their water resistant qualities can be increased by a heat treatment after they are made.

Molasses.—The active binding principle of molasses is pectin. Under the heading of molasses would be grouped all the various sugar mill wastes. There has always been a desire to adapt these wastes to briquetting, because the sugar people, well organized, have seen in the increase of briquetting practice an outlet for their waste materials. There is little difficulty in making briquettes from any good dry fine material with a molasses binder, the molasses is cheap enough and the briquettes can be kept under cover before they are used. The question may be answered thus: Good briquettes can be made with 6 to 8 per cent of molasses in the fuels and about half that addition with ores. It happens, however, that there are at present, in the United States at least, no points where fine materials requiring briquetting are

adjacent to cheap supplies of waste molasses. As a consequence, there is no commercial enterprise under way using this type of binder. It is likely, however, that in Cuba, where there is some call for briquettes, and where sugar wastes are common and cheap, that briquetting along these lines will develop. Briquettes made with molasses must be made water proof in some way, either by heat or by oleaginous admixture, or some similar method. There are binders that do better in the fire. However, a molasses bound briquette of coal, well masticated, and properly pressed is not to be despised.

Sulphite Liquor—Cellulose Liquor—Sulphite Pitch.—Under these names, and indeed a great many others, chiefly trade marks, are grouped the various forms of the paper mill waste liquor, formed as a by-product of the sodium sulphite process of paper making. In the paper mills the wood is pulped and the pulp treated with sodium sulphite, and after passing through the process, the fibre is freed from the liquor. Fibre is paper or paper material—the liquid is waste. Long and serious research has been given to the problem of utilizing successfully and commercially this sulphite liquor residuum. Evaporated to 50 per cent solution it forms a gum of wonderful adhesive properties. Evaporated to dryness and re-dissolved it has been used for many years successfully in making foundry sand cores. Its composition is exceedingly complex and varies with the chemicals used and varieties of wood involved. The composition given by Klason is as follows:

TABLE IX.

	Liquor I Kilo-grammes	Liquor II Kilo-grammes	Liquor I Pounds per short ton	Liquor II Pounds per short ton
Lignin	644	600	1,287	1,200
Carbohydrates	311	325	622	650
Proteins	15.5	15	31	30
Rosin and fat	73	30	146	60
Sulphurous acid combined with the lignin	235	200	470	400
Lime	102	90	204	280
	1,380.5	1,260	2,760	2,620

The sulphite liquor can be bought either as a 50 per cent water solution or in the dry powdered form almost completely evaporated. For briquetting purposes it is usual to buy the 50 per

cent solution in barrels or tank cars, unless the distances to be covered by freight are prohibitive. The removal of the last water from the colloidal gum is expensive, and the re-solution of the solid material for briquetting purposes also entails some expense. It is better to pay the freight on the water. The liquor is usually neutralized with lime before being sold. It is advisable, in fuel briquetting, that it be neutralized, in order to minimize, so far as possible, the evolution of SO_2 gas. In mineral and metal briquetting, it is preferable that the liquor be acid.

There are no special problems in connection with mixing the liquor with fine material. It can be done at ordinary temperatures, but some heating is part of the usual practice. The ordinary mixing suffices, but briquette quality is improved by mastication. Coal briquettes made with the sulphite liquor binder are, as is the case with starch and other cellulose products, not water proof, and must be made water proof. The method usually recommended and adopted is by heat treatment, whereby the liquor in the briquette is dried and then charred practically to the charcoal stage—dense, fibrous and water proof. Fuel briquettes made in this way are smokeless, and though somewhat brittle, and hence prone to make fines, are very acceptable to the trade. They are more expensive to make than the usual asphalt briquette. There is but one plant in the United States at present operating solely with the sulphite liquor binder—namely—The Fuel Briquette Company, of Trenton, New Jersey. In this case not all the briquettes are carbonized, many are sold in bags still "green." The objection to the "green," that is not carbonized, sulphite liquor briquette, lies in the malodorous vapors thrown off by the sulphite liquor, constituting a far greater nuisance even than coal tar pitch smoke. Inventors have tried many ways of waterproofing sulphite liquor in the briquette without carbonizing by the addition of lime, magnesia, or other material.

There is this to be said about sulphite liquor; the supply can be made enormous, provided the paper producing companies can be assured of its sale. They would then be willing to install evaporating equipment to bring the liquor down to 50 per cent moisture content. Produced on a large scale in this way, the cost of the sulphite liquor could be reduced considerably, and it is to-day as low, practically speaking, as

the heavy coal tars. Mixed at 8 to 10 per cent with anthracite coal—the most inert of the fuels— and carbonized for 20 minutes at 600° F. excellent smokeless briquettes can be made. It is not too much to predict that in the future of briquetting, both fuel and mineral, this binder will play a large and increasing part. Especially will it be welcome on the Eastern Sea Board for anthracite briquetting in those districts which have become accustomed to a smokeless fuel.

Class (D) Consists of Binders Possessing Cohesive or Glue like Properties Combined with Binders Produced by Chemical or Physical Action through the Use of Re-agents

Binders made in the briquette during the course of the briquetting process, as for instance lime, magnesia, gypsum, and especially the ferric oxide and zinc oxide mentioned in the catalytic and "corrosion" processes, take time to form. It has heretofore been the practice, where such binders are used, to briquette in a plunger press, whereby the discharge can be controlled in such a way that the briquettes, weak as they are immediately on formation, suffer no shock or fall. Obviously, where briquettes are formed on a roll press, there is an unavoidable drop from the point of pressing between the rolls to the screen or tray beneath the press. Sometimes, as in the case of the Universal press, sufficient pressure can be given to render the briquettes strong enough to stand this fall without breaking, before the chemical binder is manufactured or, colloquially speaking, before the set takes place. In such cases where it is of advantage to insure against breakage and where the roll press is recommended, on account of its very low cost of operation, it is sometimes desirable to mix the gum binder with the re-agent that will produce a secondary binder sometime after the briquette manufacture is consummated. The gum binder fulfills the function only of protecting the briquette during its fall from the press. The chemical binder formed later is water proof and strong and is depended upon to hold the briquette together during the handling and subsequent use. The water-soluble binders are the ones usually employed for this purpose: first, because the briquette will be water proof subsequently anyway, and, second, because water is usually required to make the re-agent producing the secondary binder effective.

The Ellis Binder.—The first experiments in this direction have made use of gum as the primary binder, and lime as the secondary—in some cases lime and magnesia mixed. Mr. Carlton Ellis, of Montclair, New Jersey, carried on a long research for the manufacture of coal briquettes with gum, with gum plus lime and with gum plus lime and magnesia. It was obvious that the lime contributed in a marked degree to water-proofing the soluble gum used. It was also obvious that the "set" of the lime was impaired or delayed by the presence of the gum.

The Gamble Binder.—Dr. Blake E. Gamble has taken out a patent for the water-proofing of sulphite liquor in the briquette, by the addition of other asphalt compounds or pitches. The idea is that the two different classes of binder mutually assist each other in holding the coal together, but neutralize each other so far as odor and smoke nuisance is concerned. This, is not strictly speaking, a class D binder, although a mixture of binding materials. Plants have been erected at Sunbury, Pa., and Toronto, Canada, operating under these patents.

Bureau of Mines Experiments in Duplex Binders.—The following schedule of tests made by the Bureau of Mines in the course of their long investigations with briquette binders show the results as regards coherence of mixing various primary and secondary binder materials in the manufacture of coal briquettes:

TABLE X.

RESULTS OF BRIQUETTING CALIFORNIA AND ILLINOIS COALS WITH VARYING MIXTURES OF ORGANIC AND INORGANIC BINDERS

COAL	BINDER				
	Inorganic Constituent		Organic Constituent		Grade of coherence
	Material	Per cent	Material	Per cent	
Illinois	Plaster of paris	6	Coal tar creosote	4	Fair
	Plaster of paris	6	Asphalt tar	4	Good
	Plaster of paris	6	Water gas tar pitch	4	Good
	Portland cement	6	Coal tar creosote	4	Fair
	Portland cement	6	Asphalt tar	4	Fair
	Portland cement	6	Water gas tar pitch	4	Good
	Magnesium oxide	2	Coal tar creosote	4	Fair
	Magnesium oxide	2	Asphalt tar	4	Fair
	Magnesium oxide	2	Water gas tar pitch	4	Very Fair
California	Plaster of paris	6	Water gas tar pitch	8	Good
	Portland cement	6	Water gas tar pitch	8	Good
	Magnesium oxide	3	Water gas tar pitch	8	Good
	Magnesium oxide	4	Water gas tar pitch		Fair

It should be noted that these briquettes were made on a laboratory hand press, wherein the amount of binder used is always less than roll press requirements.

In each of these cases it is apparent that the amount of primary binder required to produce the strength obtained is exactly the same as it would were no secondary binder used. The only advantage from the coal briquetting standpoint obtained in this test was the better behavior of the briquettes in the fire. In general, then, duplex binders as applied to briquetting have not had a general vogue, except in the instances designated in the succeeding paragraphs.

Hite Binder.—The C. E. Hite binder patent, controlled by the American Briquette Company, and in use at their plant at Lykens, Pa., describes a combination of two methods of water-proofing starch binder—namely, by asphalt addition, and heat. The binder mixture is as follows:

Twenty-five gallons of water are mixed with 140 pounds of globe pearl starch. This mixture is dropped slowly into 175 gallons of boiling water, undergoing a thorough agitation. The mix thickens as a starch paste and to it is added 35 gallons of melted asphalt at a temperature of 220° F. The addition is made very slowly to secure proper emulsification. When the emulsification is complete, the binder is ready for use. It is composed of 79 per cent water, 6 per cent starch and 15 per cent asphalt. After the briquettes are made, they are dried at a temperature of 325 to 375° F., which results in dextrinizing the starch, lowering the water to 2 per cent, and giving a final binder content of 1.78 per cent. The briquettes are hard and somewhat brittle; they are certainly smokeless.

ACID SULPHITE LIQUOR AND ACID TARS.

Sulphite liquor acid, or acidified, mixed with cast iron turnings and passed through the roll press has been found to give excellent briquettes, set, hard and water proof within 15 minutes after rolling. (See Chapter IV). Here the duplex binder consists primarily of lignin gum, and secondly of ferric oxide, made by the action of the acid upon the iron. Similarly, this material and acid coal tars have been used successfully and in the same way in briquetting iron monoxide, such as blast furnace flue dust, and zinc ores and oxides, wherein a zinc hydroxide binder is formed

chemically by the action of the acid in the sulphite pitch some time after the briquettes were formed in a roll press. Thus the sulphite liquor lignin gum holds the zinc ore briquette together until the oxide binder is formed. (See Chapters XIII and XIV). This application of acid liquors and tars is patented.

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CHAPTER VII.

BRIQUETTING OF WOOD WASTE

Experiments in Briquetting Sawdust and Planings — Object Sought — The Arnold System—Work of Dr. L. F. Hawley—Plant at Kingsport, Tennessee.

The problem of making wood briquettes from waste sawdust, planings and chips, has long furnished an opportunity for research and a problem of no mean proportions. Viewed from the fuel angle, it is apparent that the wood briquette cannot approach block coal in fuel value. Consequently, any work along this line must be done at a cost of operation extremely low. No large binder expense can be tolerated. In fact, practically all the work that has been done in this direction has had for its object the agglomerating of the wood chips without any admixture at all. One vital requirement must be met in forming the briquette; namely, the elasticity of the wood must be destroyed either by a high pressure or by previous heat treatment, or by a combination of the two; or the briquette formed will have no permanence. Excessive pressures are expensive and can only be justified on the score of something unique and valuable in the final product. Such has been justified in certain instances.

The writer and others associated with him have made various attempts to briquette wood on the roll press. Heretofore, the results of such work have not been encouraging. It must be remarked here that the method of pressure application in the roll press is such as to defeat the object sought in this material; namely, the destruction of elasticity. In roll press practice we do not have a continuous pressure applied simultaneously on all parts of the raw material, as is the case in the piston and mold presses. The maximum stress is applied in a succession of linear pressures, decreasing as the cross section of material increases—in a word, a "pinch" effect. Then as the cross section of the briquette decreases, the successive linear pressures increase in intensity, culminating in a "squeeze" effect, which results practically in hurling the briquette downward from the press.

A series of tests in which sawdust was mixed with coal dust and pitch binder for the manufacture of briquettes resulted in a product that was, apparently, excellent when first made. After standing for some time, the elasticity of the wood caused an ex-

pansion that first distorted and finally opened up the briquettes. Such further work as has been done along this line of attack has resulted in similar negative results. It is possible that further research may reveal a method whereby the elasticity of the wood can be destroyed completely by preliminary treatment and in that case the roll press would make as effective a briquette as it now does in the case of coal. This has not been done.

On the other hand, the technical advantages of wood briquetting are marked. Economic conditions are changing. The cost of mining and distributing coal is such that the near future may see the wood briquette enter the field as a powerful factor in the fuel supply of some sections. Indeed, some success has been met in the burning of loose sawdust and shavings under boilers. Such practice is not welcomed by the power plant engineer and is impossible in the home. Special grates and combustion chambers are required. Even with the best stoking, the B. t. u. value of loose sawdust is less than one-fourth that of good coal; whereas, by the simple process of briquetting, the B. t. u. of the wood is increased to about 7,000 or three-fifths that of good coal. In Europe—and especially in the Central Empires—where the pinch for coal has been felt so keenly in the past few years, the manufacture of briquettes from other combustible substances as lignite, peat, etc., has made good progress and wood has by no means been neglected. Previous to the introduction of the Arnold method, there had been a fairly large tonnage of briquettes made using a combination of binder and high pressure—the binder being in most cases the waste pitch from the breweries. It is not believed that this method will have much vogue in the future—especially in view of the possibility of briquetting wood without binder, thereby eliminating the mixing process and proportioning devices. There is considerable room for research as to the adaptability of briquetting of various woods. Certain it is that some are far more adaptable to the briquetting process than others.

Good briquettes have been made of wood using the piston and mold types of presses. In practice the types used have been:

1. A modification of the brick press described in Chapter II.
2. A modification of the Exter press, known as the Arnold.

3. The Gilmore horizontal hydraulic press.
4. The Duryea press.

The indications are that with the proper modifications, any one of the piston and mold types of press would suffice for the work, although it is evident that the difference in the presses would produce differences in both installation and operating costs.

The objects of wood briquetting are two.

1. The production of a briquette suitable for a domestic or power plant fuel whose use is no other than the production of heat. Such briquettes are lower in heat value than the corresponding tonnage of coal or coal briquettes, but have the advantage that the ash is an excellent fertilizer and can be bagged and sold at good prices.
2. The production of wood briquettes as a preliminary to distillation for the manufacture of wood by-products and of charcoal; or conversely the production of charcoal briquettes from fines produced by the distillation of comminuted wood. It is claimed—and with good reason—that the charcoal briquette produced by either of these methods is far better than the ordinary charcoal distilled directly from wood block.

BRIQUETTING WOOD (WITHOUT CARBONIZING).

The only installation in the United States to-day for the briquetting of wood shavings for fuel purposes is in Los Angeles, California. The Pacific Coal and Wood Company are placing the fuel upon the market, Fig. 71. The wood waste is briquetted in a special brick press. The pressure obtained is comparatively light. The briquettes are cylindrical in shape, about 3 inches in diameter and 10 inches high and are finally bound with baling wire to insure their retaining coherence under shipping strains. Though not subjected to extreme pressures, this briquette is reported to be an excellent fuel, the only criticism being that the wire in the ash causes some difficulty in ash disposal.

The Fernholtz Company is at present engaged in the design of a plant which will obviate the necessity for baling wire and it is reasonable to anticipate their success.

Fig. 71.—Sawdust Briquette Made by the Pacific Coal and Wood Co., Los Angeles, Cal.

Fig. 72.—Sawdust and Wood Planings Briquetted in Connection with the Experiments of Dr. L. F. Hawley for the Gas Defense Division. The Press Used was the Gilmore Horizontal Metal Hydraulic Press.

The Feuerlein Process.—At the Chemical Works of Carl Feuerlein, near Stuttgart, excellent briquettes are made in the ordinary Exter press, as used for lignite. The raw material is the wood residue from which pharmaceutical products have been extracted. The briquettes, therefore, are a mixture of quebracho, logwood and fustic and some chestnut and oak. On account of previous extraction processes, the wood is dry and not elastic when received. The briquettes are hard and in good demand for fuel in the surrounding district.

The Arnold Process.—The process that has made the greatest progress so far, in the briquetting of wood for fuel purposes, is the Arnold, controlled by Ganz and Company, of Ratibor, Upper Silesia. There have been many installations made, which are successfully operating to-day in Europe, of which the following are examples: E. Hagenbucher, Austria; Vollenweider Bros., Switzerland.

A description of the Vollenweider plant may be regarded as typical:

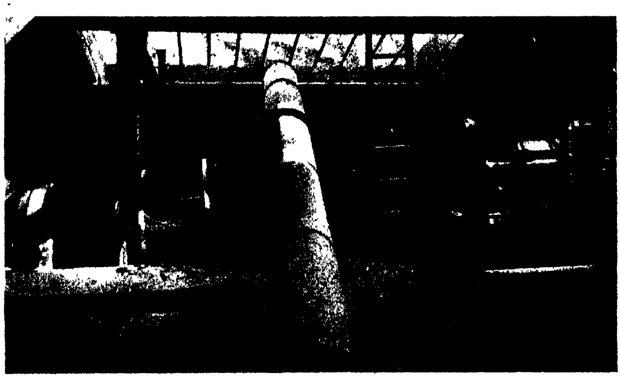

Fig. 73.—Screening Wood Waste Prior to Briquetting. Plant of Vollenweider Freres, Switzerland.

The fine sawdust is received in bins. From the bins (Fig. 74), it is delivered by suction pipe to the briquetting plant. Specifically, the delivery from the suction pipe is to a storage hopper located over a cylindrical drum dryer. This drum is supported on two steel shrouded tires riveted to the cylinder. Each

tire rests on two wheels and the cylinder is revolved by means of a pulley drive. The waste wood is fed automatically by means of a screw conveyor into a steam-jacketed chute at one end of the cylinder. Between this combined head and chute and a stationary head at the discharge end of the cylinder is arranged

Fig. 74—Sawdust Pile at the Wood Waste Briquetting Plant of Vollenweider Freres. Suction Pipe in the Foreground.

a series of steam pipes for heating the material. On the inside wall of the cylinder is fastened a series of spirally arranged baffles for cascading the material over the steam heated pipes inside the cylinder and at the same time advancing it toward and into the discharge chute to the secondary dryer. The sec-

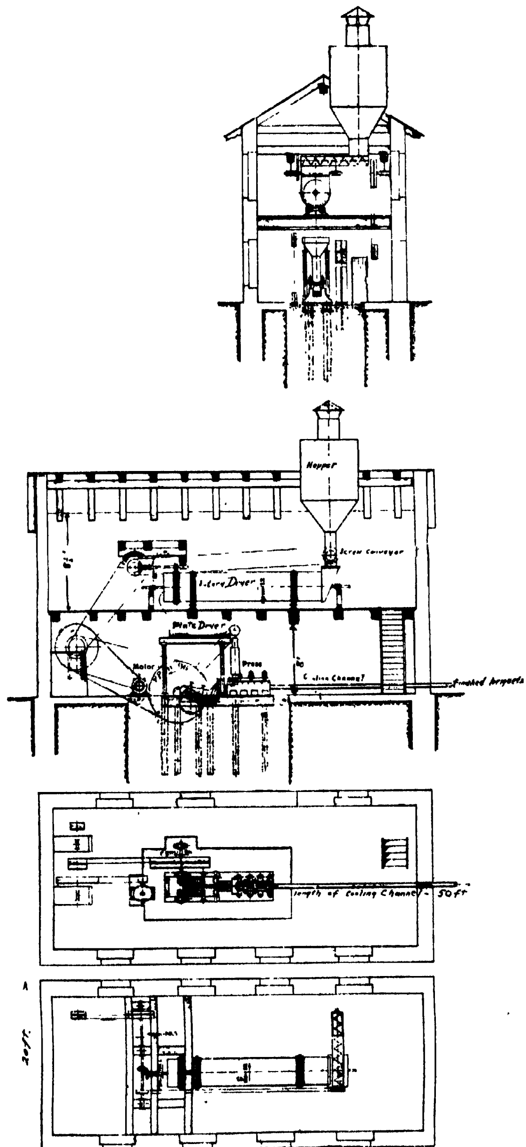

Fig. 75.—Layout of Typical Wood Waste Briquette Plant. Arnold System.

ondary dryer consists of a steam-heated plate supported by means of a cast iron frame and four columns. By means of a series of gear-driven conveying agitators, the material slides over the heated plate and a second drying process takes place, the vapors created escaping freely. The material then discharges directly into the press feed-hopper and chute, which are steam-heated. This dryer superposes the press and is an integral part of it.

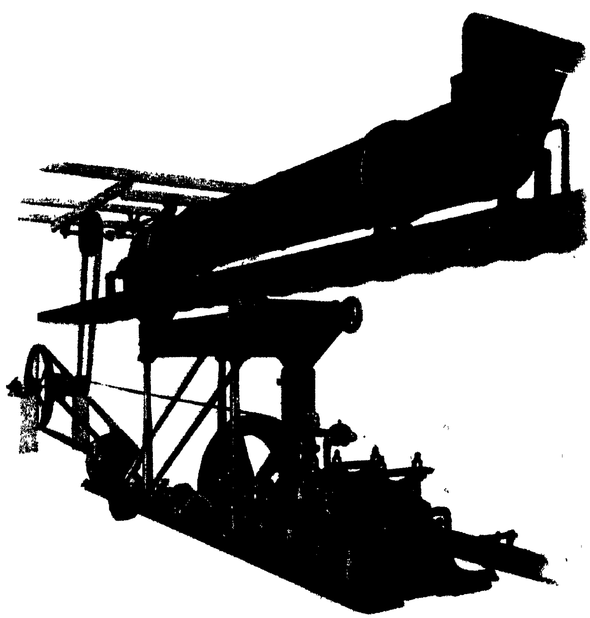

Fig. 76.—Dryers and Press. Arnold System.

This duplex system of drying and pre-heating, with its carefully calculated duration of temperature, serves to remove the moisture, to release the gums and resins of the wood without consuming them, and to destroy the resiliency of the wood particles. The steam-heated plate is especially essential, serving as a completion to the drying process and sending the material to the press with just the proper "feel and flow."

The heated material is fed to an Arnold press, an adaptation of the well known Exter press described in Chapter II. The wood is forced into an open mold by a reciprocating plunger and the decreasing cross-section of the mold provides intense pressure accompanied by a rise in temperature, induced by friction. The mold is continued, as is the practice in all presses of

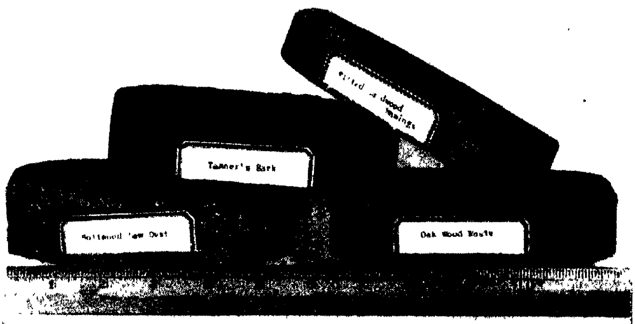

Fig. 77.—Wood Waste Briquettes. Arnold System.

the rope type, along a channel down which a series or "rope" of briquettes passes, the pulsations of the plunger serving to move the entire rope forward one briquette at a time, as well as to make the briquettes. At the end of the channel the briquettes drop into bags already placed upon the scales for weighing (See Fig. 78).

This process is destined to make progress; for it is cheap and highly efficient. Paper mills, lumber enterprises and other industries wherein are involved woody and cellulose waste can get power very cheaply by use of that waste, briquetted, for steam generation. As the moisture has been removed, the combustion of the wood briquette is superior to cord wood, all other qualities being equal. It should be noted, too, that this is practically the only feasible way by which the potash content of waste wood can be made available for the fertilizer market.

The Berner Process.—Another method of wood chip and sawdust briquetting recently introduced into Germany is the "Berner," with installations at Hudenau and Braunschweig. A "rope" of

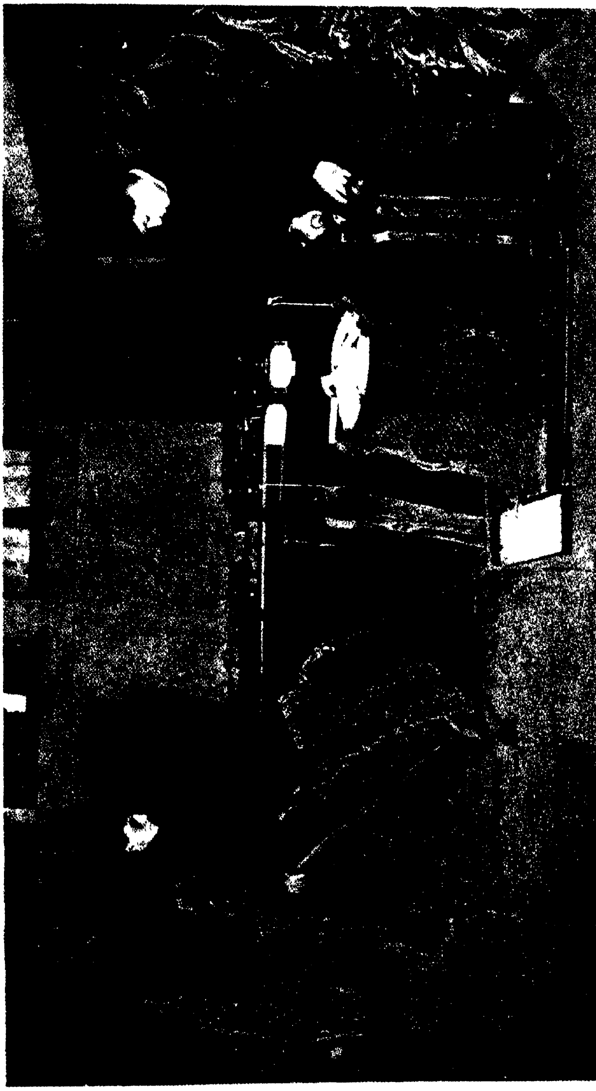

Fig. 78.—Packing Wood Waste Briquettes as they Emerge from the Cooling Channel. Plant of Vollenweider Freres, Switzerland.

briquettes is made on a light pressure press and briquettes are really "bundles." This method is adapted to the larger sizes of wood waste rather than the dust.

The disadvantages encountered in briquetting wood in the United States for fuel purposes are as follows:

1. In most localities coal is readily obtainable under normal conditions at prices well below the cost of briquetting and transportation of wood.
2. The average planing mill has but five tons per day (or less) average shavings, and the cost of installation and operating briquetting plant on such small tonnage is prohibitive. There are localities, however, where this tonnage is very considerably increased, and in these places we may look for a development of some, at least, of the wood waste reclamation methods.

CHARCOAL BRIQUETTING

There are two methods, both with powerful advocates, for the conversion of comminuted wood into by-products and charcoal. One of these calls for the distillation of the wood in finely divided form making finely divided charcoal, which must, subsequently, be briquetted; the other calls for briquetting the wood waste, and distilling the briquettes. The first method has the advantage of great rapidity in production of by-products and charcoal, but the charcoal must be briquetted and the briquettes, if wood tar binder be used, should be subjected to a carbonization or distillation process for the removal of that binder. It is, presumably, the proper method of procedure where a good serviceable metallurgical charcoal is desired. In fact, the charcoal briquette so secured is far better than the usual block charcoal product.

The Seaman Process.—The Seaman method, the invention of Stewart J. Seaman, has been installed on a commercial scale in the plant of the West Virginia Waste Wood Company at Gauley's Mills, West Va. The Seaman method concerns itself only with the production of wood by-products and charcoal, but the charcoal is produced in finely divided form and, consequently, the Dutch process of briquetting was adopted to render the product salable in large quantities.

The wood is received at the plant in a long drag scraper and consists of all the waste obtained from the saw mill. Most of the wood is in large sizes. In order to feed the Seaman retort, it is necessary that this wood be finely comminuted and it is accordingly passed through a cutting machine and "hogged." The product of this machine is a large tonnage—about 6 tons per hour—of finely divided wood waste, in condition to be fed to the retorts. Each retort consists of a rotary cylindrical drum reduced in diameter at the feed end about one-half. Above this neck is located the hopper, into which the waste wood is fed, and, operating in the neck as a piston cylinder, is a reciprocal plunger, which forces the wood waste from the base of the hopper into the neck under considerable pressure. In this manner an air tight seal is formed at the retort feed and the ingress of air or egress of distillation products effectively prevented. Each seal of raw material is broken up by the rotation of the retort after being shoved forward. A seal is always present, and the entrance is air tight. In a way this seal might be considered a wood briquette, though an exceedingly tenuous one.

The retort is heated by gas and it has been found that sufficient gas is generated by the retort for its own heating. A water seal in the gas line prevents flarebacks in the retort.

In the retort distillation proceeds with extreme rapidity. It is said that the wood is entirely reduced within 3 minutes. The vapors are carried to condensers and the usual products; namely, calcium acetate, tars, etc., are recovered. At the end of the retort provision is made for discharging the charcoal without allowing the escape of vapors or the ingress of air. The discharge end of the retort is supported on a spider (in the retort) attached to a shaft rotating with the retort on a bearing. The stationary head at this end is hollow and the charcoal passes through the spider and down the stationary head into a pocket below the retort, which discharges into a pipe. In this pipe is operated a worm conveyor carrying the hot charcoal into a hopper, whence it drops into another pipe, still lower, wherein operates a plunger similar to the one described at the feed end. The compression of the material in this pipe is sufficient to make the effective seal desired. With each stroke of the plunger a new seal is made and the seal preceding is discharged as finely divided charcoal into a screw conveyor.

The charcoal is carried from the screw conveyor to a paddle mixer and at this point it is met by a stream of cold wood tar —about 30 per cent of the charcoal by weight. It has been found that the addition of the tar—a by-product of the plant—and the hot coal serves to bring the mix to a proper briquetting temperature. From the mixer the material passes to a masticator, which serves the double purpose of masticating the mix (see Chapter X) and of finely crushing the charcoal. Such crushing is necessary at some point in the process as the charcoal as delivered from the retort is too coarse for good briquetting. From the masticator the mix is elevated directly to a rotary Belgian press (Mashek type) delivering pillow shape briquettes.

These briquettes are soft as they come from the press, but within 2 or 3 hours harden, and are suitable for shipping and for smelting purposes after this hardening has taken place. On account of the large quantity of wood tar present (and charcoal cannot be briquetted with a smaller proportion) the briquettes are hardly suitable for domestic purposes, having an acid smoke of penetrating odor. It has been found that by spreading the briquettes over the retort brickwork the hardening can be accelerated. It is the plan of the company, however, as a result of their experiments and research, to distill the briquettes in a special retort whereby the lighter fraction of the content of wood tar will be recovered, together with a certain amount of gas available to reinforce the retort fuel. The balance carbonizes in the briquette as fibrous charcoal—a wonderful bond. The briquettes that have been processed in this way are smokeless and three times as dense as ordinary charcoal. There can be no doubt but that they will be very welcome in the market.

The Heidenstam Process.—The second method for the production of charcoal from comminuted wood, is the briquetting of the wood followed by a distillation process. A great deal of work has been done in distilling ordinary wood briquettes, but the charcoal produced proved to be very fragile and, in fact, unavailable for commercial uses, No great progress was made until about 1905, when Gustav von Heidenstam of Stockholm discovered the principle of distillation of waste wood briquettes under mechanical pressures. The charcoal so produced was ex-

cellent. The process made some progress in Central Europe but, so far as the writer knows, was never introduced in the United States as such.

The arrangement of the Heidenstam apparatus is as follows:

The waste wood, containing 50 to 60 per cent moisture, is dried down to 25 or 30 per cent. A rope press, similar to the Arnold, is used in the production of briquettes, and the channel through which the rope of briquettes passes is used to feed briquettes into the charging apparatus of the retorts. The retorts consist of vertical iron cylinders fitted into ovens of special construction. The cylinders are fitted with outlet pipes at the base through which the by-product vapors pass. On the top is a cast iron cap on which the press cylinder is fixed, power being applied on the briquettes by means of a piston. The distillation requires 14 hours, and cooling another 14 hours. Then density of the resulting charcoal block is .60. The refinement of by-products proceeds along the usual lines.

GAS MASK CHARCOAL.

During the late war the invention of the gas mask made the demand for a charcoal of higher grade and purer than any before known acute. This was at first secured by the distillation of cocoanut shells; but the supply was but a fraction of the war demand.

The Hawley Process.—In 1918, the Chemical Warfare Service detailed several specialists to work out the problem, among whom was Dr. L. F. Hawley. It so happened that in addition to the need for very dense charcoal, other branches of the war department were calling for quantities of acetone and acetates far beyond the capacity of the plants of the country to supply. The answer seemed to lie in the briquetting of the wood by the most powerful pressures available and the subsequent distillation of such briquettes in large quantities.

Dr. Hawley was acquainted with the work of the Heidenstam and similar processes. He felt that by carrying the pressures much higher, the effect would be found in increased density of the charcoal.

The first experiments in briquetting were made on a testing machine improvised as a briquetting press by inserting molds between the platens (as in Chapter XV). These briquettes were

1 inch thick and about 2 inches in diameter. They were distilled in a jacketted iron pipe 2½ inches in diameter and 2½ feet long. Pressure was applied on the briquettes during the distillation by a screw. The pressure used was constant. Usually when charcoal is distilled there is a marked shrinkage in all directions. By the application of high pressure in this way, the diameter was preserved and all the compression took place longitudinally.

Following this, tests were made in June, 1918, on a Gilmore horizontal hydraulic press using pressures up to 30,000 pounds per square inch. The material was Southern pine sawdust (screened). The briquettes made were excellent, cylindrical in shape—4 inches in diameter and 4 inches high. (See Fig. 72).

Throughout this work it was found that the finer the sawdust the better the results obtained. The work proceeded on various

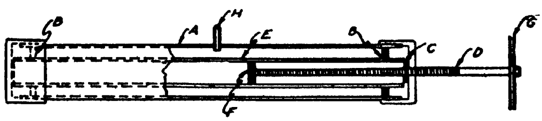

Fig. 79.—Diagram of Hawley Method for the Simultaneous Briquetting and Distillation of Wood Waste.

sorts of wood with the result that the pine woods gave denser briquettes than hard woods; but the absorption of chloropicrin expressed in minutes was lower in the case of the pine wood than in the case of the hard wood charcoal (*Note*: The chloropicrin absorption value of cocoanut shell charcoal is taken as a desirable standard; namely, 900 minutes. The chloropicrin absorption value of wood charcoal obtained so far was about 600).

The process of making ethyl alcohol and wood waste by hydralizing sawdust with dilute acid was found to give an insoluble residue of higher value to this process. A briquette was formed of this material under 35,000 pounds pressure, of density about 1.2. When distilled under a pressure of 300 pounds per square inch, a charcoal was obtained with a chloropicrin absorption value of 700. This charcoal was remarkable in character, resembling anthracite coal. It was hard and shiny and had a conchoidal fracture.

One defect in the briquettes remained to be remedied. The center portion of the briquettes was soft as compared to the end

surfaces. Dr. Hawley found that the cure for this diverse structural condition lay in varying the pressure upon the briquettes during distillation. After many tests he found that 120 to 125 pounds was the correct maximum pressure and 50 pounds the correct minimum. The recurrence of these pressures during the period of distillation in regular recurring cycles had this effect: The great pressure closed the pores and interstices of the decomposing wood at a period when its plasticity was greatest. The release of the pressure—or rather the decrease to the 50 pounds minimum—opened up new pores through which the vapors escaped and these pores were in turn closed by the subsequent pressure application. The result is the superlative of homogeneous dense charcoal. This method and the apparatus for producing the recurring cycle of pressures has been covered by Dr. Hawley in U. S. Patent 1,369,428, assigned to the United States of America.

The Process at Kingsport, Tenn.— But one large plant has been developed in the United States for the briquetting of wood and subsequent manufacture of charcoal from wood briquettes. That is the plant of the Kingsport Wood Reduction Company at Kingsport, Tennessee.

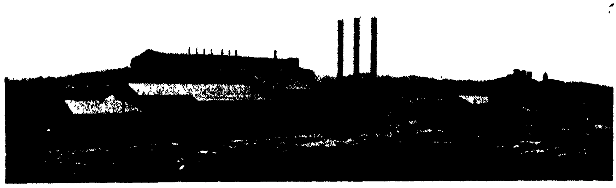

Fig. 80.—Plant of the Kingsport Wood Reduction Company, Kingsport, Tenn.

The actual construction of this plant was financed very largely by the War Department in order to obtain a large production of acetone and acetates for the Aircraft Program. It was, obviously, impossible to wait twelve months for wood to season, as was required by destructive distillation under the old methods. It was decided to put in presses for the fabrication of wood briquettes from wood waste with the highest pressures possible and to distill the wood under pressure by a method similar to the Heid-

enstam. The ground was broken for the plant in April, 1918, and the first deliveries were made the following November. The operation is as follows:

Sawdust and wood waste are delivered on a trestle in drop-bottom cars and emptied into bins adjacent to the operation. The larger waste wood is carried by conveyor to shredding machines and "hogged." All the waste wood, both sawdust and "hogged" wood, are screened in cylindrical screens. The screened material is conveyed to dryers 60 feet long, 8 feet in diameter, and the surplus moisture removed. The work of these rotary dryers combined with the extremely high pressures released on the presses employed are sufficient to make excellent briquettes without the use of the steam plate mentioned in the Arnold method. The dried wood is conveyed to eight storage bins above the press building.

The press equipment consists of eight Duryea presses as described in Chapter II. (This press was originally invented for the briquetting of brass and other metal swarf). The gas explosion, which is a feature of this press, gives a pressure that is probably beyond that released in any other known briquetting press, and by many authorities considered greater than is needed. For the charcoal work the mold has been modified to produce a briquette cylindrical in shape, 4 inches in diameter and 2 inches thick.

The resulting briquette is actually heavier than water. After their fabrication the briquettes pass down chutes to a storage bin adjacent to the retort building. They are set on edge by an assembling device into angle iron troughs 20 feet long. The troughs are mounted on a car, which serves as a medium for charging. There are twenty-six retorts in the retort house. Each retort is essentially a nest of steel tubes 5 inches in diameter and 20 feet long, the diameter being 1 inch greater than the diameter of the briquettes. The charging car is brought in alignment and as the retort heads are raised a mechanical pusher forces the briquettes into the tubes, replacing the red hot charcoal of the previous heat, which was thus shoved out at the other end.

The time of heat is 2½ hours. Great care is taken with temperature control to obtain the very highest quality of wood products. As the briquettes become plastic, pressure is generated against them by the use of hydraulic compression plun-

gers. The intense density of the wood briquette, the compression of the charge, together with this accurate control of heat, produces a charcoal which is claimed to be unequaled in gas absorbing power. The chloropicrin absorption value is not stated. It is further claimed that the tars and other wood products are superior in quality to similar distillates obtained in the ordinary processes of wood retorting. The handling of these products after distillation is very similar to the methods employed in other up-to-date plants. These products consist of calcium acetate, tars, creosotes, oil and pitch. The plant has a capacity of one hundred cords hardwood per day.

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CHAPTER VIII.

THE BRIQUETTING OF PEAT.

Peat or "Turf" is a decaying vegetable matter, disintegrated wholly or in part, usually brown in color. It is convenient to designate peat geologically as the first step in the formation of coal beds—the sequence being:—growing vegetation, peat, lignite, sub-bituminous coal, bituminous coal, anthracite, graphite. It should be said that geologists are not in accord as to the evolution of all coal beds through these stages. It is however true that there are many kinds of peat grading from incipient decay to the loosest of lignite structure.

Peat, in the United States at least, is primarily used as a fertilizer. The familiar form is the bagged "humus" as it is called by fertilizer companies. Peat also serves as raw material for the manufacture of paper stock. Alcohol has been made from it. It has antiseptic properties, and has been used for hygienic purposes notably for wound bandages. In Europe, especially Ireland, Scandinavia and Russia, it is a staple fuel. In Central Canada there are no coal beds, but an abundance of peat bogs. For three decades the Canadian Government has worked to find the place of peat in their gigantic endeavor to make Canada fuel independent. In the United States peat is found in abundance in the New England States, New York, Michigan, Wisconsin, Minnesota and along the northern border of the states of New Jersey, Ohio, Indiana, Illinois and Iowa. Peat seldom occurs in coal regions.

These peat bogs constitute an enormous fuel reserve. In fact, the recent advance in coal prices has inspired renewed investigation of peat fuel possibilities. It has become increasingly evident that the science of briquetting, properly applied, may bring a good merchantable fuel of this class on the market, and that too, on a large scale. Opinions differ as to the time when briquettes of peat will begin to be featured by those engaged in the business of marketing fuel in North America. The writer believes that such a time is not far distant, and that the necessity for close study of the technical and financial aspects of the situation is upon us.

CLASSIFICATION OF PEAT

In all cases the disintegration of vegetable matter forming peat has occurred under water. It is necessary for peat formation that there be an area of depression, having a clay bottom whereon still water lies, favorable to the growth of aquatic and other plants. What are known as "high bogs" are principally made up, so far as their peat content is concerned, of the remains of mosses, moor plants and forest residue. The vegetable matter forming the 'low bogs" is usually composed of grass sedge and weeds. Bogs may consist of mixtures of the two genera of plants. Botanically speaking, the following sub-divisions of the plants usually occurring in peat formations has been made by J. Hallmén of Markaryd, Sweden.

Moss Peat:

(a) *Sphagnum Peat,* made from sphagnum moss.--This class is difficult to dry, is very light, and well adapted to the moss litter industry and for bandage purposes.

(b) *Hypnum Peat.*—This class is rich in lime and nitrogen and is better suited to fertilizer rather than fuel purposes, although it does not absorb moisture to the great extent common to the Sphagna.

(c) *Forest Moss Peat.*—This class consists largely of forest residues and when properly treated can be made into excellent fuel.

Grass Peat:

(a) *Sea Peat,* made from the remains of low order ocean weeds. Properly disintegrated and treated, it makes excellent fuel.

(b) *Carex Peat.*—These plants are usually the products of sandy soils; therefore, there may be a considerable admixture of silts and sand, resulting in high ash content. Some bogs, however, of this class have delivered excellent fuel.

(c) *Eriophorum or Cotton Grass Peat.*—This class has the best raw material for the manufacture of peat fuel when the contents of the bog have been well disintegrated. When not disintegrated, the fibre is strong and attempts have been made to make fabric therefrom.

Another classification is that cited by S. W. Johnson:

(a) *Turfy Peat.*—Yellowish brown in color, spongy and elastic, but slightly decomposed.

(b) *Fibrous Peat.*—Brown in color, less elastic, but with the fibres of the vegetation easily distinguishable by the eye.

(c) *Earthy Peat.*—Without fibrous structure, being an earth-like mass, breaks with some difficulty.

(d) *Pitchy Peat.*—Dense and black with a lustrous fracture.

In this division only (b) and (c) are of importance in the discussion on peat briquetting. Class (d) would in all probability operate in a manner similar to lignite, and class (a) would be more valuable for purposes other than fuel.

The chemical composition of peat is complex. Peat originates from cellulose or vegetable substance and lignin or woody matter. These compounds are formed of carbon, oxygen and hydrogen. Mixed therewith are more complex compounds—resins, fats and proteins. During the decomposition that results in peat, the humic, ulmic and like acids are formed. The cellulose seems to be the least disturbed of the vegetable compounds concerned. Bitumen is common to all classes of peat. The decomposition is accompanied with a gas formation in which are included carbon-dioxide, methane, ammonia and hydrogen sulphide.

A typical proximate analysis of high-grade peat is as follows:

1. Wet		2. Dry	
Moisture	91.02	Water	0
Vol. matter	5.37	Vol. matter	59.80
Fixed carbon	3.00	Fixed carbon	33.41
Ash	1.61	Ash	6.79
Sulphur	.11	Sulphur	1.22

The analysis speaks for itself, and betrays the usual difficulty encountered in preparing peat for fuel purposes. Dry peat compares very favorably with any high-grade fuel, but there is a vast amount of moisture to remove. It has been noted that in Holland prices have been realized for good peat fuel 15 to 20 per cent higher than prices obtained for coal in the same locality. A typical ultimate analysis for peat is:

	Per cent
Carbon	58
Oxygen	35.0
Hydrogen	5.7
Nitrogen	1.2

The first objection raised against peat for fuel lies in the fact in the United States that the country is already well supplied with fuels of other kinds. This fact has practically halted investigations of the possibilities of peat during the past two decades. It is a fact that a new fuel has a greater difficulty finding a market than any other type of novelty. No one likes to try an experiment whose failure would result in a succession of cold and uncomfortable days. Again, the fuel trade is conservative, well organized and ready to oppose the introduction of new products. None the less, there are places in America where fuel is high, where a peat bog is near and where an excellent market within a radius of 50 miles of the plant could be built up in short order.

Where such a market is available the next step is the examination of the peat bog. As has been said, peat for fuel purposes should be well disintegrated in place. Nearly all peat averages about 90 per cent moisture in the bog, but a reduction of 10 per cent can be made if opportunity is at hand for proper drainage by means of canals. Unless the peat is to be transported by pumps (which is not usual) drainage facilities should be given first consideration.

The methods at present in vogue for preparing peat fuel are two in number as follows:

1. **Cut Peat:**
    (a) By hand.
    (b) By machinery.
2. **Briquetted Peat:**
    (a) Pressed in peat machines.
    (b) Pressed in piston briquette presses.
    (c) Pressed in roll briquette presses.

Cut Peat.—Cutting peat by hand is the oldest and simplest method of preparation. It is still used almost entirely in Ireland and some parts of the Continent. The work is performed as follows:

The bog is first drained by deep ditching, followed by leveling and digging of a series of small ditches. The surface of the bog is divided into squares. One man cuts the peat, using a tool known as a slane, and places the peat on the edge of the trench,

while the other loads it on a wheelbarrow and lays it out on the drying field. Work commences as soon as frost has left the ground. On the drying field the briquettes are placed in conical heaps or stacks of any convenient shape to obtain the greatest possible surface. The air-dried peat contains about 30 per cent moisture.

The cost of production in the pre-war period was less than $1.00 per ton. The fuel was satisfactory for its purpose, but could not be handled roughly, nor transported long distances.

Fig. 81.—The Slane—The Tool Used for Cutting Peat by Hand.

The cutting of the peat by machinery was of course bound to follow the comparatively laborious hand methods. It should be noted that cutting machines are badly hampered where logs or stumps occur in the bogs. A typical cutting machine is the Dolberg, and the methods employed by this machine are similar to those of others, such as the Heinen and the Weitzmann. In the Dolberg peat cutter, the cutting tool consists of three sharp-edged vertical plates, which are pressed into the bog by a rack and pinion. When it reaches the desired depth, a lever moves an undercutting plate, which cuts off the block of peat and holds it while it is elevated. The machine securely mounted can be moved as wanted over the bog. The guide is movable on a frame. Two men are required.

Production with this device varies with the conditions. The bricks are 9.2 x 4 x 4. A good production is twelve thousand per day. When so large an output occurs, it is sometimes convenient to build drying racks or drying sheds in place of spreading the blocks on the ground to dry. By this means a more rapid and efficient drying is secured.

Machine Peat.—Broadly speaking, blocks of peat may be considered briquettes, even when they are nothing but squares cut from a bog. Similarly, the same term may apply to all classes of formed or pressed or condensed peat. It was early discovered

that the cut peat blocks lacked firmness, had small fuel value per unit, and still retained a high percentage of water. It was found that mechanical treatment prior to the shaping of the peat lowered the percentage of retained water and raised the density and fuel efficiency of the peat. The first step in advance consisted in throwing new cut peat into the hole left from the previous season. Water was added and the mixture tramped out by feet or hoofs. When the mixing was completed, the pasty mass was taken to the drying ground and cut in squares. The fuel so produced was denser, stronger and burned better. As a further step in advance, wooden troughs were used as receptacles during the maceration. It was not long before devices were on the market whereby this maceration was done in a trough, the peat and water mix reduced to a slurry, while moving forward under the revolution of knives mounted on a shaft. The slurry was dumped into molds of uniform size where peat blocks were formed. Later the peat blocks were removed from the molds and air-dried. Methods of this sort persist on a small scale in Ireland, Denmark and Sweden, but have found little favor elsewhere.

The forming machines have been a more popular method of work. The pioneers in the machined or briquetted peat industry were C. Schlickeysen of Germany, who manufactured the first machine in 1859, and T. H. Leavitt, in the United States, who founded and operated a peat condensing factory at Lexington, Mass., about 1865.

The first machine manufactured by Schlickeysen consisted of an enclosed vertical shaft provided with knives. The raw peat was fed through the top, macerated, and forced through a mouthpiece of abridged cross-section, being at once cut into lengths. His machine embodied the principles upon which most of the later designs operated. Later rugged tearing apparatus was included, to take care of roots and fibres.

The machine now offered by the Schlickeysen firm is illustrated in Fig. 82. The raw peat is fed to a hopper and torn by disintegrating members operating in opposite directions, at the same time throwing it against a roller, whence it drops into a trough containing revolving knives, mounted on a shaft, operat-

ing against fixed bars. The knives are set in the manner of a screw thread and force the pulped material through a constricted opening. The extruded peat is cut into briquettes, which are carried to the drying racks.

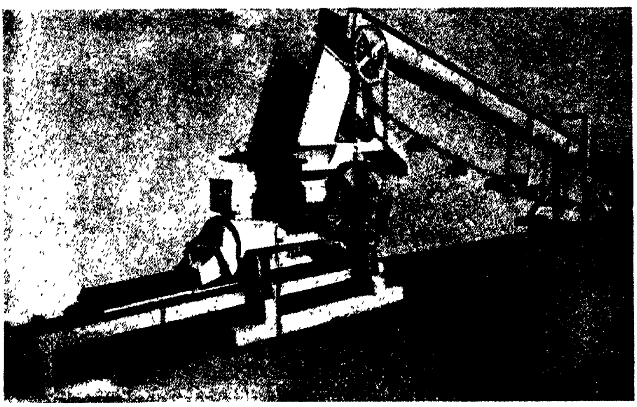

Fig. 82.—The Schlickeysen Peat Machine.

The appearance of the first Schlickeysen machine was followed by a number of others similar in principle—notably the Dolberg, Heinen, Sugg and others. In practically all cases these machines consist of parallel twin shafts carrying revolving knives, operating against each other, forcing the material to a constricted opening as above described. These machines could only be used successfully on well humified bogs. Each manufacturer offered in addition, as did Schlickeysen, a modified design carrying special machinery, adapted to the heavier work incident to peat winning in fibrous and stump filled areas.

To-day the design by Anrep is the one in most widespread use—in fact most of the European peat machine factories have taken out licenses under the Anrep patents. This design was notable in that it combined the simplicity of the machines adapted to well humified peat, with a ruggedness that obviated the necessity for special construction in handling fibrous and woody material.

Machine 1B is shown in Fig. 83. This machine has a hopper widened at the bottom to prevent bridging by stringy matter. The trough in which the knife-bearing shaft revolves consists of two

cylinders, each ending in a truncated cone, the cone of the first cylinder being joined to the second cylinder. Over the wide cylinder is the feed. In this cylinder six fixed knives are inserted in the bottom of the shaft, carrying shaft bearings. The rotating knives, as well as the fixed ones, are of exceedingly strong construction, and operate against each other with a scissor-like effect. In the first truncated cone is a screw-thread with sharp edges, cutting against knives on either side. The second cylinder has five fixed knives through both bottom and top, carrying the shaft bearings. The shaft in the second cylinder carries a double screw-thread

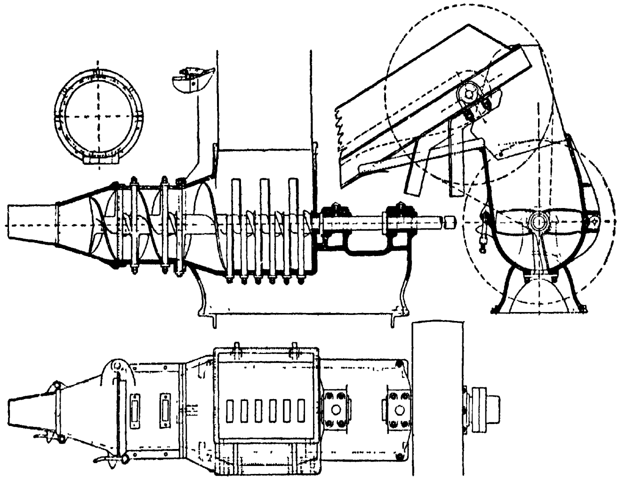

Fig. 83.—Modern Anrep Peat Machine.

with two knives, or a series of knives as desired. The second truncated cone provides the usual truncated mouthpiece, whose narrowing cross-section acts as a press against the peat, shoved forward against it by the screw-thread. The extruded peat is cut into blocks in the usual way, and sent to the drying racks.

The peat mass coming from this machine is well pulped. The fibers and roots are disintegrated. The resulting product is excellent fuel.

In the United States the pioneer in practical peat fuel production was Mr. T. H. Leavitt of Lexington, Mass. He founded a plant at Lexington in 1865 and operated it until 1871, market-

ing peat fuel in that vicinity. Mr. Leavitt's entire life was given up to the study of peat, and of the various products derived from peat as the raw material. Subsequently a plant of his design was established at Orlando, Florida, in 1905, under the auspices of the Water and Electric Light Co. of that town.

The Lexington outfit consisted of two parts—the condenser and the molding mill. The term condenser is Mr. Leavitt's own, and is perhaps a happy one, as disintegrating action in all peat machines does result in a condensation of the product, owing to the expulsion of air and water. The condenser consists of a series of revolving cylinders. The peat is put into a hopper and meets a cylinder with projecting lugs and a shaft carrying revolving knives. Then it passes through a series of revolving cylinders, similar in construction to the first, revolving at different speeds, the final cylinder being without the projecting lugs. The first series tear and disintegrate the peat, the latter knead it. The mass passes from the condensing machine, reduced in bulk about 25 per cent, and runs over to the molding device. (Fig. 84).

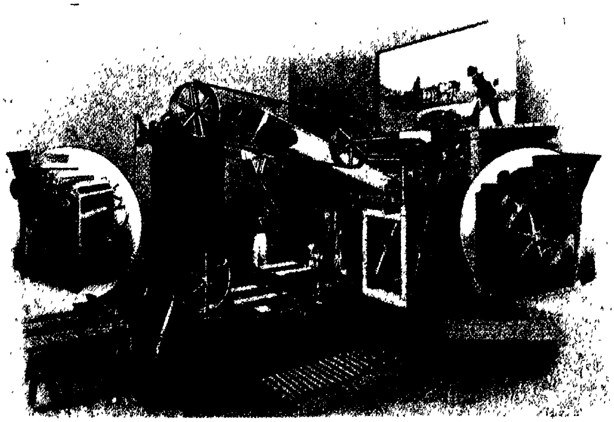

Fig. 84.—Leavitt Peat Condensing and Moulding Mill.

The molding machine consists of a cylinder vertically placed, containing a vertical revolving shaft to which are attached heavy iron blades. Between the blades are fixed plates of iron with apertures. Below this cylinder revolve two drums carrying the

molds. The condensed peat mass is forced over the aperture into the molds of the revolving drum. But little pressure is used. By means of a cam arrangement, the peat bricks are ejected from the molds after a semi-revolution, being picked up at the base of the machine by an apron conveyor. The blocks are then dried in racks or on the ground.

It is not believed that any of the Leavitt machines are operating at the present time, owing to economic conditions. In Europe, and especially in Germany and Sweden, the inventions of Schlickeysen and Anrep and others have developed an industry. According to last reports, Russia, including Latvia, Esthonia, Poland, and Lithuania, alone is using about 1,500 Anrep machines, and producing 5,000,000 tons of machine peat annually. The total for Europe has been about 10,000,000 tons, chiefly in Russia and Scandinavia, and to a far less degree in Ireland. The Irish bogs have not as yet yielded readily to the machine peat methods. Heretofore Germany has been fairly well supplied with coal and lignite, and it has not been easy to produce a peat brick at a price that would compete with their "Braunkohle." In the United States but little has been accomplished. It can readily be understood that with a coal supply so rich that even the lignite deposits are practically untouched, there has been little demand for peat as fuel up to the days of stringency during and after the late war. In Canada the story has been different, and for many years there has been a continuous effort to find a substitute for coal in the great peat bogs of Ontario. The Canadian Government has spent a very large sum of money in investigating possibilities. It would be very desirable from their point of view to have the population of the Provinces of Quebec, Ontario and Manitoba, in which practically no coal exists, burn Canadian peat rather than American coal.

CANADIAN "PEAT FOR FUEL" RESEARCH

The first investigations involving plant construction were in 1901. The plant was built at Welland, Ontario. The peat was won by harrowing the ground exposing a layer about 2 inches deep. After about 2½ hours this layer, sun-dried to 45 per cent moisture, was scraped off. Artificial drying was used afterward. The dryer was known as the Simpson. It con-

sisted of two parallel revolving cylinders longitudinally superposed, made of sheet iron. Within the cylinders were iron stirrers. The peat passed through both compartments and was dried to 25 per cent moisture. Unfortunately the cost was too high, and artificial drying was abandoned as has been the case in practically all attempts at peat briquetting. The peat was then disintegrated and conveyed to the press, which was specially designed for the purpose. It was known as the Dickson type. The construction was peculiar in that it had an open mold vertically placed, but without the construction of the mold usual in the typical Exter press, described in Chapter II. The briquettes were weak.

On account of the high cost in drying, and the inefficiency of the pressing operation, this plant was closed down a few years ago.

The second attempt at briquetting peat in Canada was at Beaverton, Ontario, by the process invented by Mr. A. Dobson. This operation started in 1902. The peat was won by a mechanical excavator modified by Mr. Dobson. A paddle wheel excavator, revolving very rapidly, picked up the peat and showered it over the surface of the bog to a distance of 30 feet, thus spreading it in excellent condition for sun drying. After 2 to 3 hours air drying, the peat was scraped off mechanically, loaded on cars and sent to the disintegrator. This machine consisted of a cylindrical case, enclosing a revolving shaft on which cast iron lugs are mounted. On these lugs are arms, each suspending a row of cast steel fingers. As the shaft rotated rapidly the steel fingers, operating against a grizzly set beneath, disintegrated the peat. From the disintegrator the thoroughly broken mass was conveyed to the Dobson dryer. The Dobson dryer was simply a modification of the ordinary shell dryer. The peat conveyed to it contained 34 per cent moisture and was reduced to 16 per cent. From the dryer the peat was carried to a galvanized iron hopper serving as a press feed. The Dobson press was in principle somewhat similar to the familiar rotary horizontal table presses, described in Chapter II. It was however not built to withstand great pressures. There were two revolving mold tables, and two pressure plungers. The briquette remained in its mold for one entire revolution of the press, and was subjected to another

compression by another brick being formed on top of it. After the second compression the briquette was expelled from the press. This was done by releasing a punch worked in the next die to the compressing punch. Between pressures the molds were swabbed with oil to prevent sticking of briquettes in the mold. This press made fifty to fifty-one revolutions per minute, producing one hundred briquettes. Twenty-five briquettes weighed 10 pounds. It is quite evident that both these methods were producing excellent fuel, but were too expensive in operation and were finally dropped. They are interesting to one investigating the briquetting of peat, for they prove that drying by heat and pressing on machines of the piston and mold type are hardly practicable for such exceedingly low grade fuel. It should be said that every care was taken to keep down expenses and obtain low costs of operation in both these runs. Their final abandonment leads to the conclusion that the bulk of the moisture in peat must be removed by the sun; that at present writing the peat fuel industry must be seasonal, for such drying can only be accomplished in the summer, and, finally, that improvement over the product of the machines of the Anrep and other types of similar character seems in general to be had at an expense not justified by the results. However, later investigations seem to show exceptions.

A very interesting series of experiments are reported by Dr. J. McWilliam in a bog near London, Ontario, in 1916. To Dr. McWilliam, be it understood, belongs the credit of using the vacuum principle for picking up the sun-dried peat from the surface of the bog after harrowing. The field is harrowed in the ordinary way, and 2 hours later a fan collector is passed over it picking up peat dried down to 30 per cent. A later operation at London used a steam plate dryer, bringing the moisture down to 15 per cent, but Dr. McWilliam, in spite of the previous experience of Canada with the Simpson dryer, advocates the rotary principle in drying with the cascade effect. He reports his first experiments as having been with the Milne press (a Belgian type) with which 1,500 tons of good briquettes were made, containing 6 to 12 per cent moisture. It was found that on this type of press the range of allowable moisture was small, and the manufacture was therefore difficult to control.

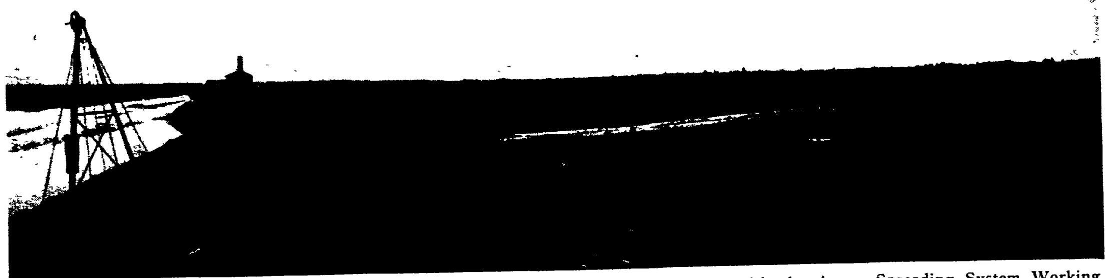

Fig. 85.—Excavating and Molding Machine Designed by Ernest V. Moore Coupled with the Anrep Spreading System Working on Alfred Bog, Ontario.

Accordingly, the installation of a special Duryea type press, using the expulsion cylinder followed. This press was modified, so that three briquettes weighing 1 pound each were made at once. The top pressure of 450 tons was divided between the three briquettes and of course extremely good fuel was made. It may be assumed that this operation was entirely experimental. Nothing was said about cost, but from what the writer knows of the cost of operation on this type of press, it is hardly to be believed that its use in the peat field will become very widespread.

In 1908 the Canadian Government sent agents throughout Europe to investigate the production of peat and to make report in full. This report was made by E. Nystrom, M. E., and was published by the Department of Mines in Canada in 1908, under the title—"Peat and Lignite—Their Manufacture and Uses in Europe." Acting upon this excellent report, the Bureau of Mines installed an Anrep machine, recommended by Mr. Nystrom as the best suited for that purpose, at the Alfred bog in Ontario. The plant was in operation in 1910, and 1,500 tons of peat fuel were made and distributed with gratifying success in Canada. As a result of the demonstration, private parties took over the plant from the Government, but, being under-capitalized, failed, and the Government is again operating the plant to-day, and now has two machines in operation—No. 1, the typical Anrep layout, and No. 2, a similar layout, improved by Mr. Moore, the resident engineer. Plant No. 1 made 2,000 tons in 1919, and plant No. 2, about 700 tons. The work is going ahead. The costs shown are $1.05 per ton for plant No. 1, and 60 cents per ton for plant No. 2.

WET CARBONIZING

In Great Britain the most interesting contribution to peat fuel science is the "Ekenberg wet carbonizing process." This process has been improved at various times, and, though brought out in 1904, has not yet been used on a large scale. On the other hand, it is quite possible that the improvements recently made by Testrup, Rigby and others may result in a more widespread use of the process.

In this process the peat as obtained from the bog is charged into retorts and heated up to 150° C. At the same time a pressure is generated up to eight atmospheres. The large bulk

of water surface in the peat is a heat conducting medium, allowing charring to take place, the charring medium being the hot water. The following results are noted:

(a) The peat loses its colloidal structure, facilitating the removal of water afterwards.

(b) A slight charring takes place causing the material to turn black.

Fig. 86.—Machine Peat Blocks Made at the Alfred Bog, Ontario, with Machines Installed by the Canadian Peat Committee.

(c) The hydrocarbons (gas and liquid) that would ordinarily pass off in a dry distillation are retained in the fuel.

(d) The moisture can be easily pressed out of the charred mass and briquettes can be made on an open-mold press from the residue.

In 1904 the Swedish Government voted 20,000.00 kronen for experiments on a large scale with this process, with which a plant was established at Staffjö, and later a company known as the Wet Carbonizing, Limited, established a plant at Drumfries, Scotland, in the vicinity of a bog excellent for their purpose.

At the Staffjö plant the peat is pulped in a machine of the Anrep design, from which the mouthpiece is removed, and a perforated steel plate substituted. The peat coming out of the machine is cut away from the perforation by means of a rotating knife. The mass is now a homogeneous pulp and is transferred to a silo or storage tank of six days' capacity. From

the silo the peat is carried to a pump by an elevator. The pump forces the pulp into spaces between two concentric pipes. The smaller pipe revolves and has on its periphery a screw-thread. This thread shoves the peat pulp forward. The length of the pipe system is 37 feet. (Figure 87). The peat mass, forced forward to (b) from inlet (a) by means of screw-thread mounted

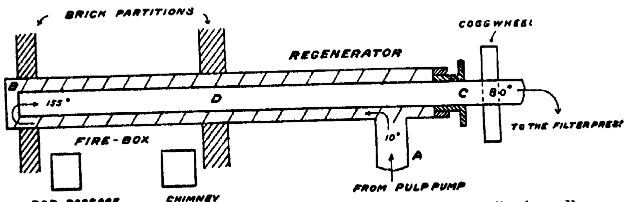

Fig. 87.—Diagram of the Working of a Wet Carbonizing Oven. Ekenburg Process.

on pipe (d), turns at (b) into the pipe (d) and, is ejected at the outlet (c). This pipe system is heated from a furnace, and a temperature of 150° C. is realized at the charge. The carbonizing time is 15 minutes. In order that no steam be formed in the system, a pressure of ten atmospheres is maintained in the pipes by the pump. The carbonized peat is conveyed to a filter press, and the remainder of the operation is drying and briquetting in an open-mold press, in accordance with the methods used in the German "Braunkohle" briquetting. The Staffjö plant was entirely experimental and was not intended as a continuous commercial performer.

The Swedish Government abandoned the investigations of the Ekenberg Process in 1906, and the Staffjö plant was abandoned. This, however, was prior to the improvement of the process by Nils Tesrup and T. Rigby.

The plant at Drumfries was operated along similar lines by Wet Carbonizing, Limited, but was not a financial success. With the outbreak of hostilities the discovery was made that the peat formed by the Wet Carbonizing Process was a good, smokeless fuel, and could be made easily, and with the support of the British Government the plant started operation again. The modification by the gentlemen al.eady mentioned was incorporated in the new design.

In this plant peat with 93 per cent moisture is pulped and forced under hydraulic pressure into steam-jacketed pipes, of 2-inch tubing, wherein the wet carbonizing takes place; thence it is forced by a pressure of 120 pounds per square inch into filter presses, the moisture being reduced to 25 per cent. The filter cake is pulverized and the powder is blown up through the boiler flues, reducing the moisture to a negligible amount. Briquettes are then made upon the open-mold press.

RECENT WORK ON PEAT FUEL IN THE UNITED STATES

So far as peat fuel was concerned, no notable invention was put into active use in the United States after the work of Mr. Leavitt, until quite recently. In 1918 the United States Geological Survey reported that the amount of peat fuel manufactured and brought to market amounted to 20,567 tons. The bulk of this peat came from New England and the producers were George W. Hall, North Adams, Mass., A. N. Pierson, Cromwell, Conn., Roger Upton, Marblehead, Mass., L. F. Farwell, Lewiston, Maine, the New Era Development Co., Shirley, Mass. With the exception of the last named, the peat marketed and sold by these interests was peat cut and dried by means nearest at hand without great expenditure for a plant. The New Era Company, however, constructed their plant in accordance with the patents of Dr. C. D. Jenkins, and were the only producers to report a tonnage of peat fuel made and sold in 1919. The plant as designed by Dr. Jenkins is as follows:

The Jenkins Peat Processes.—The essential feature of the original Jenkins' machine consists of a main frame divided into sections—one of which houses a screw conveyor feed, and the other the cams and molds of the briquette forming apparatus. These two units are operated by separate drives. In the first part of the operation the peat is fed into the wide portion of a conical chamber, horizontally placed, in which a powerful screw conveyor turns. The screw conveyor carries a cutting blade. As the material is forced forward, the cross-section narrows, and considerable pressure is thereby brought to bear upon the peat in a manner very similar to the usual peat machine.

The briquetting apparatus consists of two wheels, joined together, forming a unit rotating in a vertical plane. The wheels are in a recess formed by two vertical plates, enclosing the side

of the wheels, the plates being secured to the vertical frame, and carrying the bearings of the wheel shafts. The shafts connect with the outside gear, driven by the wheel pulleys. Each wheel is provided with a series of radial cones, which form, with the stationary side plates, a plurality of mold chambers, open on the periphery.

Each of these mold chambers has a movable bottom, provided with fingers straddling the wheel ribs, and with cups, which project into a recess in the stationary plate. These lugs are acted upon by a cam, whose operation keeps the mold bottoms at a uniform distance from the shaft until they reach the discharge point, when the cam movement throws the lugs forward, and the bottoms, projected upwardly, eject the briquetted peat from the mold.

In operation, the material, well pulped and under increasing compression, is forced down the screw conveyor casing to the mold chambers, which are filled at the discharge point of the screw conveyor. On arrival at the press feed, the pressure causes a diminution of volume and increased density. As the wheels turn the mold is closed by coming in contact with the exterior casing, and the pressure thus maintained. The material rubs against this bottom casing under pressure throughout the lower 180 degrees of the revolution. At a point directly opposite to the feed, in a horizontal plane, an opening is provided in the casing for discharge, and the throw of the cam movement comes into play, ejecting the finished peat brick.

The frame and casing are piped and recessed to carry steam or flue gases, so the entire operation is carried on under heat. The peat is therefore discharged in a thoroughly dried and baked form.

Dr. Jenkins has improved this process and the New Era Development Company will continue operations with a horizontal feed press. The press has been described in Chapter II.

THE ZWOYER UNIVERSAL PRESS APPLIED TO PEAT.

In 1920 Mr. M. G. Ewer of the Peat Products Corporation started a technical investigation for peat fuel along different lines from those heretofore attempted. In conjunction with the General Briquetting Company he had a series of tests run upon

the Universal press (described in Chapter II). The laboratory report of the tests in question is quoted herewith:

> "Peat contained 35 per cent of moisture, was masticated hot and rolled on a Universal press. Good briquettes were obtained. On drying a marked shrinkage occurred together with hardening of the briquettes. The briquettes had several minute cracks, but were very good and would stand drop from considerable heights."

As a result of this experiment, the Peat Products Corporation have set up a press at their bog at Eaton Rapids, Michigan, and are turning out a good grade of peat briquettes at the present time, which they are selling at good prices in the neighborhood of Grand Rapids, Michigan and vicinity. The process is exceedingly simple, consisting of passing the air-dried peat, in this case containing about 35 per cent of moisture, directly into the Universal press. It is probable that a change in the peat structure is caused by the successive linear pressures produced by this press, and that the water is thrown from its colloidal condition in somewhat the same manner claimed for the Ekenberg process. At all events, the peat which has reached its limit of air drying at 35 per cent goes through a secondary drying after it is in the briquette form, accompanied by setting and hardening. The result is a hard, shoveling fuel, as convenient to handle as coal, with an excellent radiating heat value. It is customary to appraise fuels in accordance with their B. t. u. content, and on this basis the peat briquette mentioned would be worth 67 per cent of coal prices. Some have maintained, and the writer among them, that the regular form of all kinds of briquetted fuel and the nature of its combustion results in a radiating or heat-throwing power which, for stove or hearth use at least, gives the briquette a value far beyond what its B. t. u. content would indicate. This is especially true of the peat briquette. In addition, when pricing this product, the fertilizer value of the ash must be considered. So, it might not be out of line to anticipate a selling price for the peat briquette not far below that of the best coal in a given district. It is quite probable that the hardening and intense binding effect produced during the drying and shrinking of these roll-press briquettes is due entirely to hydrolysis of cellulose, as is the case in the drying and shrinking of machine peat. Certainly in this instance, it occurs to a more pronounced degree. The briquettes as they come from the press are weak and soggy.

They must be spread out to dry. In drying they shrink from a 2 inch square edge to 1⅜ inch. When coming from the press they are not weather-proof, but they become weather-proof with time. The writer believes that this phenomenon is partly due to the action of combined nitrogen in the peat, which in ammonia form would normally make the peat bitumen soluble in the water. After the evaporation of the ammonia, the bitumen would return to its normal insoluble state. At least, it may be safely assumed that some such action occurs to assist the binding quality and the weather-proofing of the hydrolized peat that holds the particles together.

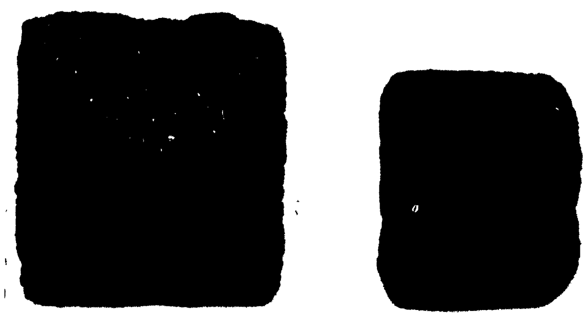

Fig. 88.—Peat Briquetted on Universal Press.
Left—Size of Briquette as it Comes from the Press. (35 per cent Moisture). Right—Briquette after Air Drying. (Actual Sizes).

It would seem for the American market at least, where a shoveling fuel is considered absolutely necessary, that the roll-press briquette, made in so simple a manner as the above, will come into its own in districts but sparsely supplied with coal, as in New England and the North West. It may very well be that the future of peat fuel in America depends upon a proper combination of a pulping machine, like the Anrep, and a roll press like the Universal. It is certain that the water cannot be pressed out by hydraulic presses, that artificial drying is too expensive, and that the simplest methods of drying and pressing must be adopted. It is, in truth, hard to find anything simpler

or better adapted to the people it is to serve than the above method.

By far the major portion of peat briquettes produced has been used directly as fuel. Peat briquettes properly made are an excellent household fuel. The combustion is slow; the fire is well sustained and will keep well over night. The B. t. u. content is about two-thirds that of coal and the price to be obtained for peat briquettes is therefore not so high as good coal fuels can obtain. There are, however, two other uses for peat briquettes other than serving the domestic stove and furnace. Peat briquettes have been used for the production of peat charcoal or coke—an article which has been found equal and even superior to good wood charcoal. Peat bricks have also been made successfully for paving purposes.

PEAT CHARCOAL

Peat charcoal or peat coke can be made by coking in heaps in their familiar crude manner employed by charcoal burners in primitive forest districts. There has been a considerable amount

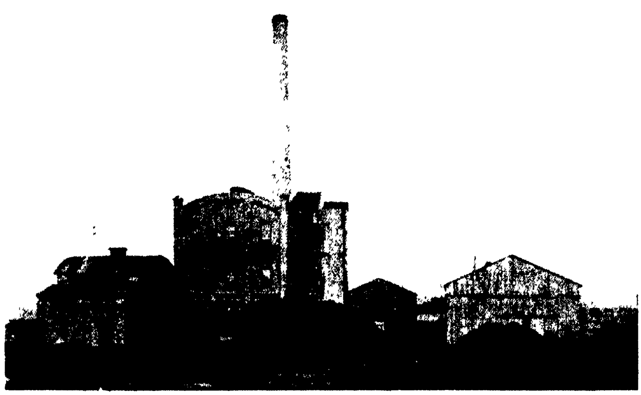

Fig. 89.—Peat Coking Plant at Oldenburg, Germany—Ziegler Process.

of charcoal made this way at Triangel, Germany. Several types of non-continuous ovens have also been devised, but their use has in no way become successful commercially.

The Ziegler Process.—On the other hand, one process for coking peat is said to have outgrown the experimental stage, and that is

the Ziegler, under which system four plants have been installed; namely, at Oldenburg, Germany, Redkino, Russia, Beuerberg, Bavaria, and at Dartmoor, England. In the Ziegler process the usual method is to carbonize the air-dried machine peat briquettes, containing about 25 per cent water, in upright retorts. The peat is conveyed at the top of the ovens and the coke is drawn off from the bottoms of the retorts into cars, which are heated to prevent combustion during cooling. From the by-products of the process are recovered paraffin, creosote, oil, gas, ammonium sulphate, acetates and wood alcohol. In addition are the gases which are used as fuel for the retorts. In this process the best peat is used to form a charcoal for smelting purposes. The highest ash peats are used to produce a semi-charcoal, wherein a certain part of the oil matter remains—an excellent domestic fuel. At the Redkin plant this half coke is produced for a railroad fuel. After the operation the vapors generated are drawn off by an exhaust fan and driven to a con-

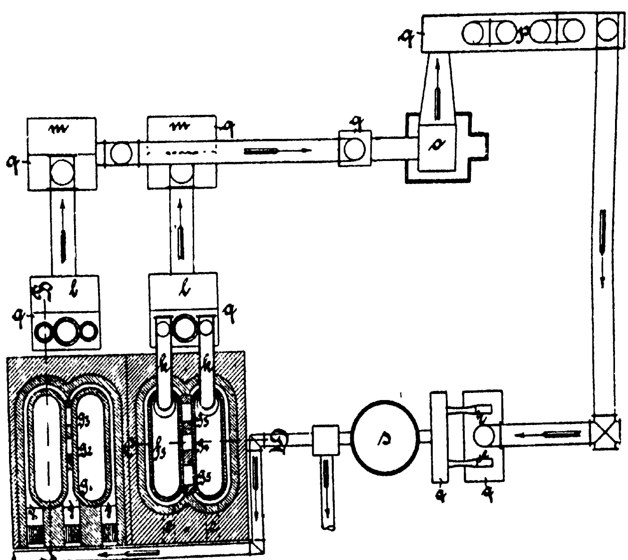

Fig. 90.—Ziegler Peat Coking Ovens, as Erected at Beuerberg, Bavaria.

a. Hopper.
c. Feed Boxes.
d. Furnaces.
fg. Flues.
k. Distillate Pipe.
lm. Collectors.

denser where they are condensed. The non-condensable gases are sent to the furnace for heating the retorts.

Each unit of the Ziegler process consists of two vertical retorts about 40 feet high with the elliptical cross-section. They rest on a cast iron foundation above which is a hopper with two openings for drawing off the charcoal. At the top are cast iron covers carrying the feed boxes. The highest temperature in the retorts is about 600° C. The following is a typical analysis of the peat coke obtained:

	Per cent		High	Low
Carbon	87.8	Calorific value in calories per kg.	7,889	7,805
Hydrogen	2.0			
Nitrogen	1.3	B. t. u. per lb.	14,200	14,049
Oxygen	5.5			
Sulphur	0.3			
Ash	3.2			

We may safely consider the Ziegler process as a technical success, although some of the plants that have installed it are said to have met with financial difficulties and are no longer operating.

Mr. M. Ziegler has worked out in Germany recently a system of peat treatment and briquetting in connection with Krupp, Gruson Werk, Magdeburg.

The procedure is as follows:

1st Stage.—The peat, having a moisture content of from 90 to 95 per cent, is shredded, but not too fine, and squeezed out by a simple press, to 80 per cent moisture.

2nd Stage.—This material is taken to another automatic press (hydraulic) where the moisture is reduced to 65 per cent.

3rd Stage.—This material is mixed with coke breeze or coal dust and then briquetted in rotating table presses. Still more water is pressed out (about 300 kg./cm. pressure). This is possible with relatively low pressure after mixing with coke, coal, etc. Briquettes which were made on a laboratory press looked very good. The product can be sold raw, or, if the peat is wanted for the production of coke, the product is dried by waste heat—after the second stage—and then fed into the retorts, as above.

It is claimed a plant can work during the whole year with this method, and that frozen peat is, if anything, pressed with greater facility. The end product has 5,000 calories per kilogram. The peat is figured at 2,600. From this the ratio of the two ingredients may be calculated.

It is claimed this method can also be applied to lignite and coal. However it is apparently founded upon methods long discarded on this hemisphere.

Schoening Fritz Process.—This interesting process has been commercialized by the Deutsche Torfkohlen Gesellschaft, who erected a small plant at Halmsee, Germany. A further installation has been made near Stettin, which has a capacity of somewhat over 3 tons briquettes per hour.

The peat is disintegrated in the usual manner. Thence it passes through a series of three horizontal retorts, being carried forward by screw conveyors operating within the retorts. The peat gas is used as retort fuel. The mass passes through the retorts in one-half hour, which time suffices to bring about a partial carbonization. The maximum temperature in the retort is 250° C. The heated semi-char is conveyed to the molds of a heavy hydraulic press—a modified Ronay (Chapter II) would be excellent for the purpose. The press plungers are heated to 200° C., and bring a pressure to bear of three hundred atmospheres. The pressure is sustained for 12 seconds.

As a result the briquettes are heavy and strong, and burn with a long smokeless flame. It is very evident that unless fuel made in this way could command a substantial premium over coal prices, it would not pay to install such a factory in the United States.

Willmarth Process.—The most interesting design for the production of a carbonized peat fuel is that of Mr. C. A. Willmarth. It is understood that a Willmarth plant will shortly be erected in the Middle West. The system consists of the following:

The raw peat is thoroughly disintegrated, and, when dried down to 25 per cent moisture, is put through the retort, and the by-product is recovered together with a certain amount of peat charcoal. The warm charcoal is then mixed with 50 per cent of air-dried peat, thoroughly beaten together and the mixture briquetted

in an open-mold Exter press, as used in the German Braunkohle industry. It is understood that the experiments and preliminary work undertaken in connection with the process have been exceedingly promising.

Hammerling Process.—A chapter on the various methods of briquetting peat would be incomplete without mentioning the Hammerling process for making artificial wood blocks from peat by briquetting methods. The peat is cleaned, and mixed with a hydrate of lime and argillaceous earth containing a proportion of sulphur. The mixture is then pressed in molds in a convenient press, the pressure being exceedingly light. It remains on for a few seconds, when the mold is released and the briquette removed and air dried. It is stated that the wood made in this way is suitable for floor walks, ornaments, and especially for railroad ties, having the advantage that no impregnation with creosote is necessary. A plant was started at Pompton Plains, New Jersey, but is not understood to be at present in operating condition.

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CHAPTER IX.

THE BRIQUETTING OF LIGNITE OR "BRAUNKOHLE."

According to Reinhardt Theissen, the foremost authority to-day on fuel structure, *Lignite* is "a residue consisting of the more resistant plant substances in a macerated and changed condition. The debris is composed of (a) cellulosic substances in a greatly altered condition, tissue fragments, cell complexes, single cells and fragments of cells, (b) resinous substances, (c) cuticles, (d) spore exines, (e) pollen exines, (f) miscellaneous debris. The ratio of the cellulosic components to the resinous components varies inversely to the state of maceration and degree of metamorphism."

It is readily to be seen that a technical differentiation between peat and lignite at the one end, and peat and sub-bituminous coal on the other end, is to the highest degree difficult. The best differentiation is that proposed by Marius Campbell; namely, in accordance with carbon-hydrogen ratio. For its value as a classification for all fuels, it is inserted herewith:

TABLE XI.

		Carbon hydrogen ratio
Group A	(graphite)	∞ to ?
Group B	anthracite	? " 30
Group C	anthracite	30 " 26
Group D	(semi-anthracite)	26 " 23
Group E	(semi-bituminous)	23 " 20
Group F	(bituminous)	20 " 17
Group G	(bituminous)	17 " 14.4
Group H	(bituminous)	14.4 " 12.5
Group I	(bituminous)	12.5 " 11.2
Group J	*(lignite)*	*11.2 " 9.3*
Group K	(peat)	9.3
Group L	(wood, cellulose)	7.2

A practical distinction, based on briquetting characteristics, is easy. When the cellulosic substance is so far metamorphosed in the decaying carbonaceous structure that the peat machine is not practicable, and other methods become necessary for practical preparation, the line between peat and lignite has been passed. On the other hand, lignite, as the name implies, retains evidences of woody structure to an extent that distinguishes it from the coals. Further, most lignites, under weathering or ordinary com-

bustion, disintegrate into small fragments, "slacking" in a manner utterly fatal to fuel efficiency. Lignite, therefore, cannot be transported long distances, nor burned "as is" to advantage. It has, therefore, offered a fertile field for the briquetting investigator.

The geographical distribution of lignite has furnished a further impetus to research for its successful utilization. The occurrence of lignite is unusual in the neighborhood of coal beds. (Similarly peat bogs do not occur in the vicinity of extensive coal or lignite deposits). Lignite is common in tertiary formations. In the United States the extensive fields are two:

1. The Southwest Field—underlying the greater part of a region beginning in Southeast Texas and running northeast to Western Tennessee—a belt about 500 miles wide.

2. The Northern Field—underlying the greater part of the West Dakotas and Eastern Montana extending northward far into Saskatchewan.

Lignite of a superior grade is found in Colorado, Wyoming, California and elsewhere outside the two great belts mentioned. In Canada, too, beds exist in the Hudson Bay District in Ontario, and elsewhere. The northern districts of Canada can hardly be said to have been explored. Important lignite deposits occur near Dawson in the Yukon province.

Three widely different methods are in practice for the briquetting of lignite.

1. The German "Braunkohle" method; whereby the lignite is dried to a proper consistency and briquetted without admixture in an "Exter" type press.

2. The lignite is mixed with binder and briquetted, by coal briquetting methods.

3. The lignite is carbonized or distilled, with or without the recovery of by-products, and the char briquetted by coal briquetting methods.

I—The German "Braunkohle" Method.—Lignite briquetting in general, and lignite (braunkohle) briquetting without added binder in the open-mold press in particular, has attained great popularity in Germany—so much so that other countries may be said to have merely scratched the surface in comparison. The German braun-

kohle is the ideal material for the Exter press. The briquettes there made are hard, of fine appearance, resistant to weather, burn well and without nuisance, hold their shape in the fire—all to the entire satisfaction of the German consumer, though the calorific value is low in comparison to bituminous coal. The size (7 inches x 4 inches—1-pound weight for example) is satisfactory for the character of heating appliances there in vogue. Between 16,000,000 and 35,000,000 tons are annually marketed.

A typical layout of a Braunkohle briquetting plant is illustrated in Figure 91.

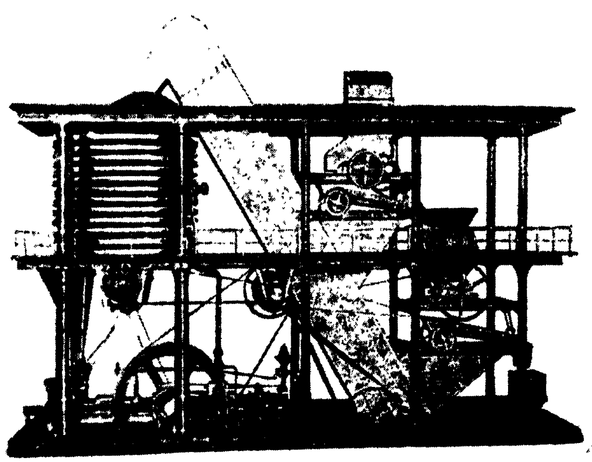


Fig. 91.—Typical German Braunkohle Briquetting Plant as Installed by the Zeitzer Eisengiesserei und Maschinenbau A. G. (Steam Table Dryer on Left Above, Press Immediately under it).

The braunkohle or lignite is won in open pits, usually, though in some cases underground mining methods are employed. The material as mined contains 48-58 per cent water. The seams are often 60 feet thick. From the mine the coal is conveyed to the briquette factory—by chain conveyor or aerial tramway, for the factory is ordinarily nearby.

At the factory the crude lignite passes from storage to a wet crushing treatment. The coal is unloaded into hoppers, by hand or by machine tippers. Feed rolls deliver the material from the

hoppers to toothed crushers. These crushers vary in size and strength, according to the amount of stumpage and wood fibre in the crude lignite. In some instances where the lignite is thoroughly humified, smooth roll crushers are used. Centrifugal pulverizers and beater mills are used in some instances.

After the crushing a screening operation follows. Flat sieves are almost universally used at this point, as the lignite is still very wet. The general practice is to divide the crushed material into three parts— (a) fine, (b) intermediate, (c) oversize and chips. The fine (a) is chuted to the drying house, the intermediate (b) is sent back for further crushing and sieving, and (c) the oversize, with its contained fibre, is transported to the boiler house to be used for power generation.

Drying the briquetting coal is an important phase of the operation. The amount of moisture varies from 40 to 60 per cent and it is usual to reduce it to 15 per cent. To do so requires the evaporation of large quantities of water—thus:

TABLE XII.

Per cent water in coal	Per cent water in briquetted coal	Per cent water to be evaporated per lb. briquettes calculated to moisture free
40	15	41.7
45	15	54.6
50	15	70.0
55	15	88.9
60	15	112.5

It was formerly the practice to introduce hot flue gases direct upon the braunkohle, as is done to-day in anthracite briquetting—but the explosion risk is great, on account of low volatile gases present and the low dust kindling temperature characteristic of lignite. The practice is now prohibited in Germany by police regulation. Steam drying is to-day practically universal. As the presses require considerable power and are steam driven, waste steam is usually present in quantity requiring but little reinforcement. The steam dryers consist of a series of tubes through which steam passes—at about three atmospheres pressure—its heat being conducted through the tube walls to the lignite contained in the space surrounding the tubes.

At one installation the vapors arising from the drying lignite are conveyed to the point where the crude material enters the factory and the vapor heat is utilized to preheat the lignite before it enters the process.

There are two main types of steam dryer in vogue:

1. The steam table oven.
2. The steam drum tube dryer.

A typical table type of dryer (Figure 92) consists of a superimposed series of double-walled hollow iron tables, resting on four hollow columns circumferentially located at equal intervals. In the centre of the apparatus revolves a shaft, carrying stirrers, which rotate over the tables. The stirrers consist of rods, on which are bolted sheet iron plows, passing over the tables in such a way that the drying coal is shoved spirally along the surface of each table, beginning with an outward movement and dropping to the next table close to the periphery; on this table the movement changes direction toward the centre, and so, continuing alternately, until it is finally discharged, dry, from the base. Means are provided for admitting steam into the hollow tables and for carrying off the condensed water. Two of the four vertical columns act as steam pipes, and supply the steam through twin pipe lines to the interior of the table. The other two columns serve as runoffs for the condensed water. Every care is taken in construction to render the tables steam tight, and strong enough to retain their flat surfaces under trying conditions.

Each sector of the steam table (eight sectors in all) has openings for the discharge of material to the table below. Tables discharging from the inner circle have eight openings. Those discharging on the periphery have twelve openings. The drop is about 10 inches between tables. The thickness of the table—upper and lower shell and steam space—is about 2 inches. The stirring gear makes three to six revolutions per minute. There are 1,500 to 2,000 shovels in all mounted on this gear. The number of tables is 30 to 37—usually counting the lower four as cooling tables, not always present. The drying surface is between 4,500 and 7,500 square feet, varying with the size.

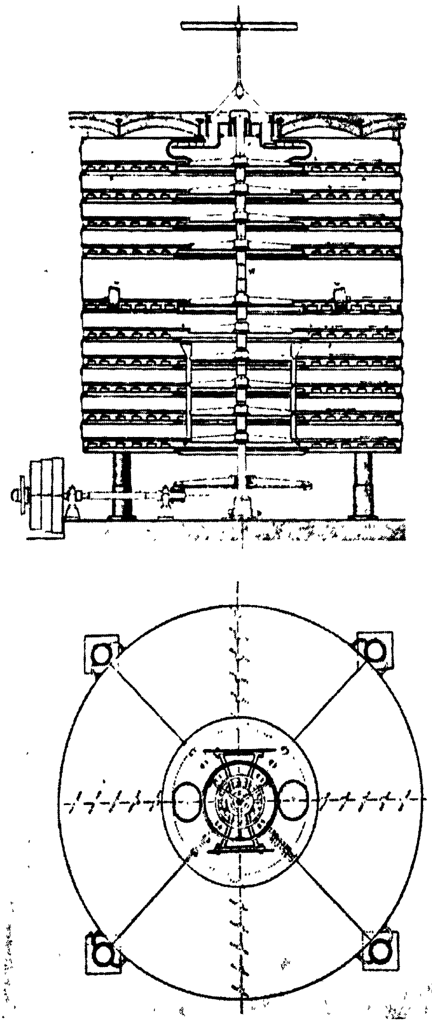


Fig. 92.—Steam Table Dryer for Drying Lignite. Cainsdorf Design.

The drive is effected through a large gear wheel keyed to the main shaft, and a bevel wheel, carrying at the far end of its shaft a three-speed cone pulley and friction coupling. The horsepower requirement is usually 9-10.

The dryers are encased in sheet iron. The casing is provided with doors for the regulation of air supply. The vapors coming off the lignite pass through a funnel to the outer air, meeting a series of dust catchers on the way.

The capacity depends entirely upon the amount of moisture in the coal to be treated. Roughly speaking, a twenty-five table oven, drying from 54 per cent to 15 per cent, would handle a little over 2 tons per hour.

2. The steam drum tube dryer.

Practically all installations using this type follow the designs of R. A. Schulz—so that most tubular steam drum dryers are known as Schulz dryers.

This type consists of an inclined cylindrical drum of boiler plate, carrying a second drum of much smaller diameter with coincident axis—this second drum, or pipe, being perforated along its entire length—and a series of smaller diameter drying tubes arranged in concentric series. The drum is revolved on its longitudinal axis by means of a worm. (Figure 93).

The wet coal passes from the charging hopper into the tubes—and by the rotation and inclination of the apparatus—passes down to the discharge. Waste steam is admitted to the hollow interior drum and, passing through the perforations, is distributed throughout the large drum, surrounding the tubes. The condensed steam is removed from the bottom of the drum by drain pipes to the lower axle tube, whence it is discharged. There are three drain tanks equi-spaced on the circumference, into which the water drains when they are at the lowest point of their revolution, and, being prevented by valve action from returning into the tank as the rotation proceeds, the water empties into a curved pipe, down which it is conveyed by gravity to the axle head.

The coal, dried to the desired point, drops from the tubes to the trough of a worm conveyor and is taken to the press.

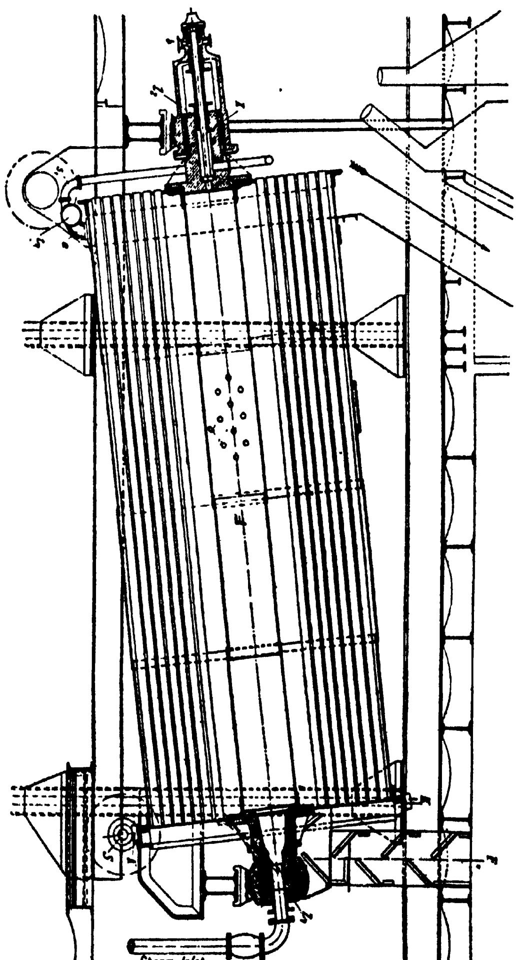


Fig. 93.—Schultz Steam Dryer for Lignite. Section.

The following dimensions show the relative proportions of a Schulz dryer:

Length of drum:	20-23 feet
Diameter of drum:	7-9½ feet
Angle of	5°-7°
Revolutions per minute:	4-8½
Diameter of central drum:	242-366
Diameter of tubes:	About 4 inches
Total heating surface:	4,300-8,400 square feet
Horsepower:	5 to 8
Capacity:	45-70 tons per 24 hours

In Central Europe the advocates of the table and the drum systems are fairly well divided. Authorities state that each has its special sphere. In general, the advantages of the drum system

Fig. 94.—German Braunkohle Briquettes in Storage Shed. (The Briquettes Made by the Johnson Fuel Co., of Scranton, N. D., are Very Similar to These in Size and Shape).

are greater capacity and, consequently, lower cost per ton and less floor space required; the installation cost, too, is much less. For the table dryer claims are made espcially on the ground of accessibility, repairs being easily and quickly made. The table process is susceptible to far closer control than is the drum.

In at least one German plant the combination of both systems has been used. In America the Schulz or similar type only has been used for lignite preparation where the "braunkohle" method

of briquetting has been used. In all these cases, however, steam drying is essential. It is said by German authorities that the braunkohle industry of Germany owes its existence to the application of steam drying.

Fig. 95.—A German Braunkohle Briquette Factory. Wilhelmina Mine. Frechen, near Cologne.

From the steam dryers the coal is conveyed, usually by spiral worm, to the coolers. The coal emerges from the dryers at about 150° F. As the temperature of the coal rises rapidly during briquette formation, it is essential—in order that good briquettes be obtained—that it be cooled between the drying and pressing operations.

Where the table type of dryers is used—as above mentioned—the three or four lowest tables—unheated, or with their chambers filled with cold water—are used as cooling surface. The rabbling assists the cooling, the coal being brought down to 85° F. If the coal is not sufficiently disintegrated, it is crushed, usually between smooth rolls, screened, and passed through mixing conveyors.

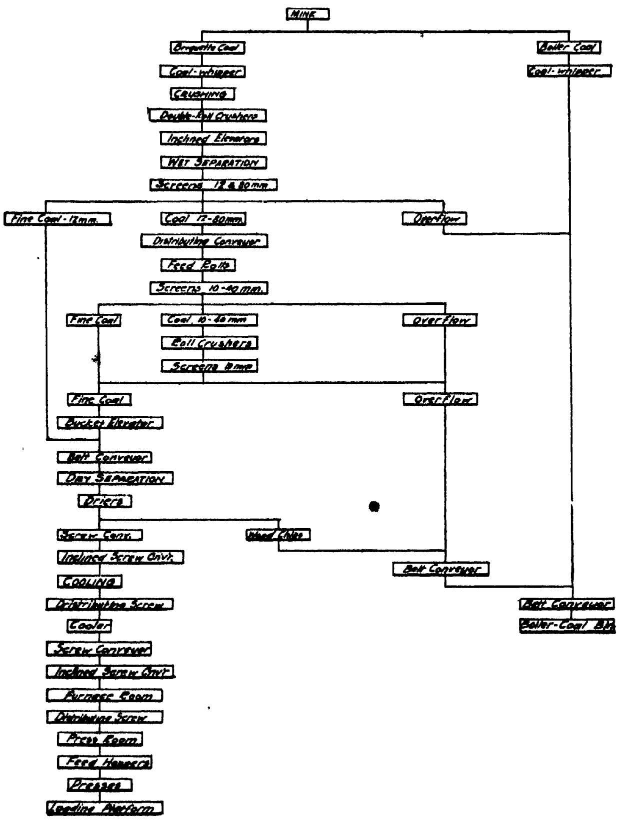
Boiler-tube coolers have been used; and independent table coolers, similar to the lower tables of the steam dryer, are fairly common. A device known as the Rowold oven, too, is met with, fulfilling the function of cooling briquetting coal. This apparatus consists of a double series of sheet metal slides—bent to about 145°, arranged in alternately staggered fashion, facing each other in echelon, as one is one-half below the other. The coal passes down the plates in zigzag fashion, and is thoroughly permeated by cold air entering from side slots in the enclosing cylinder.

The lignite, dried, cooled and thoroughly mixed, passes to the press hopper. The press is invariably of the open-mold Exter type—described in Chapter II. Great care is taken to see that the mix is of the proper texture and temperature before putting it through the press.

The heating up of the press must be gradual. At the same time it is impossible for the press to operate successfully cold. It is the custom, therefore, to mix the lignite with oil during the first part of the run. Gradually, the friction of the press builds up a heat at the sides of the channel and little by little the oil content is reduced until the press is operating upon the natural lignite cooled as aforesaid. It is customary for the various factories to put their trade marks upon the plunger, which is thereby impressed upon the briquettes. As the briquettes are made at extremely high pressures—sometimes as high as 24,000 pounds per square inch—they come from the press quite warm. Along the cooling channel the row of briquettes is formed, pushed forward by the piston as each new briquette is made. In this channel the cooling takes place most effectively, provided the channel is long enough. It is the best German practice to give the briquette "rope" a cooling time of three hours. A cooling trough must be so arranged to allow for an expansion of the briquette amounting to one-tenth of its length.

Loading of large size briquettes is done by hand, similar to wood waste briquetting. See Figure 78. Some of the factories make three small briquettes at o~ce instead of one large one by having the pistons or plungers of the presses operate in

triplicate, forming in this way a shoveling briquette, which, in Germany, is generally called for at power stations, the large briquettes being better suited for households.



Flow Sheet—Typical German Braunkohle Briquette Plant.

The growth of the braunkohle briquette industry in Central Europe has been due not only to the advantages of the fuel itself, but to concentrated efforts by a powerful combination to bring before the public the peculiar advantages of this fuel. It is commonly said that Berlin and similar cities owe their very clean appearance to the consistent use of braunkohle briquettes in

households throughout these cities. The advantages pointed out are the complete combustion of the fuel, freedom from smoke (comparative), simplicity of stove operation and, of course, the moderate price. The briquettes have been used successfully in boiler firing and it is said that the figure at which they equal the performance of bituminous coal is between two-thirds and three-quarters the price of that coal. This coincides with the difference in B. t. u. value between the two classes of fuel.

In the United States there have been constant efforts to adapt this system of lignite briquetting to the various lignites previously mentioned. In 1903 Frank H. Mason, Consul General of the United States at Berlin, received samples of Bismark, N. D. and Alabama lignite, representing the two big fields of the United States. These lignites were turned over to German factories for experimental work and it was found that both lignites made very good briquettes. The Alabama lignite proved to be especially suitable, molding into shining hard briquettes of wonderful cleanliness. Since that time there has been a tendency—chiefly Governmental in character—to apply the German process to the United States, but it has not been found uniformly successful with all classes of lignite, just as in Europe the Bohemian and most of the Hungarian lignites have been found likewise unsuitable to the "braunkohle" method.

The Bureau of Mines between July 1st, 1908, and June 30, 1909, ran an exhaustive series of tests both on the German method of briquetting lignite, as hereinbefore described, in comparison with ordinary coal briquetting means applied to raw lignite. The object of these investigations was to determine:

1. The possibility of briquetting American lignites without adding binder to them.

2. The suitability of the German brown-coal briquette presses for briquetting American lignites.

3. The percentage of moisture needed in the briquette material to give the best briquettes.

4. The approximate commercial cost of briquetting lignites.

5. The weathering qualities of briquettes as compared with raw lignite.

An additional purpose of the tests was to provide a supply of lignite briquettes from which to determine their value as (a) steaming fuel under boilers, (b) gas-producer fuel, (c) domestic fuel.

The plant was installed at Pittsburgh, Pa., and consisted of bins, bucket elevator, roll crusher (corrugated), a Schulz dryer (steam), a plate type cooler of construction similar to the table dryers installed in many of the German briquetting plants. This cooler consisted of a series of stationary tables over which four radial arms carrying vertical rabbles rotated, giving the material centrifugal and centripetal actions alternately. From the bottom plate the cooled material went to the press. Dust stacks were installed at the delivery end of the dryer to prevent explosion trouble. A typical Exter brown-coal press (Buckau), was installed, and parallel to it an English revolver type of press (Johnson). The former was to demonstrate the feasibility of German brown-coal briquetting practice on American material; the latter to investigate the possibilities of making large raw lignite briquettes by piston and mold methods with added binder. It was as a result of these tests that the important conclusion named in Chapter VI, namely, that lignite containing less than 1.4 per cent of matter soluble in carbon bisulphide is not capable of briquetting by the German method, was reached. The results of the tests are published in *Bulletin No. 14*—Bureau of Mines. It was found that of the samples submitted the Ione lignite of Amador County, California, gave the most satisfactory briquettes. The second was the Scranton, N. D. sample, the third Medina County, Texas sample and the fourth, the Lehigh, N. D. sample. There were, however, North Dakota samples as well as Texas, which did not give satisfactory results and, in some instances, briquettes failed to form. It was found, too, that not all the briquettes resisted the weather equally well. A test was made in which three samples of raw lignite and eleven samples of briquettes were placed in the open weather for 286 days. The California lignite raw disintegrated to some extent, but not nearly so much as the others. The briquettes from California and Scranton, N. D. lignite stood up very well.

Following the Government tests in 1909, the Ione Coal Co. in California erected a plant located at May, near Ione, in Amador

County, California, in 1915. The engineering work was done by the Fernholtz Machinery Co., of Los Angeles. The operating company was called the Lignite Fuel Co. The operation is understood to have been successful during that year. The equipment followed closely the usual German design consisting of bins, Schulz tubular steam dryer, table coolers and the Fernholtz modification of the Exter press, followed by cooling channel; together with the necessary conveying machinery.

In 1909 the United States Fuel Briquette Company experimented in the briquetting of Montana lignite at Deer Lodge. Very little information is available as to their results. They ceased manufacturing very soon after starting.

It is also recorded that in 1909 the Pacific Coal Briquette Company at Marshfield, Oregon, installed a German press to briquette Coos Bay lignite by the German method. The project was not commercially successful and was dropped.

In September, 1916, Mr. Charles A. Johnson, President of the Johnson Fuel Company of Fairfax, S. D., shipped some North and South Dakota lignite to the Fernholtz Company in Los Angeles. Briquettes were made by the German system in this company's testing plant, to Mr. Johnson's satisfaction. He then had a long series of tests run in the Lignite Fuel Company's plant, above mentioned, with the result that he bought the plant complete and set it up again at Scranton, N. D. Under the auspices of the Johnson Fuel Co. in 1919 the plant was enlarged to three units and further enlargement is projected.

The Johnson Fuel Company mines their lignite with steam shovel, the veins being close to the surface under a burden of less than 40 feet. (See Figure 4, Chapter I). From the mines it is carried to the plant and dumped by an automatic device into a large coal crusher, thence to a disintegrator designed by Mr. Fernholtz. The disintegrated lignite is screened over a shaking screen and it is carried thence to the steam dryers—a modification of the Schulz type. The dryers reduce the coal to the consistency mentioned hereinbefore as suitable for open-mold press briquetting. From the dryer it is conveyed to a large receiving hopper from which it descends into the intake chute above the briquette press. By automatic weighing, the proper amount is fed to each pulsation of the press to make a single briquette. As is usual

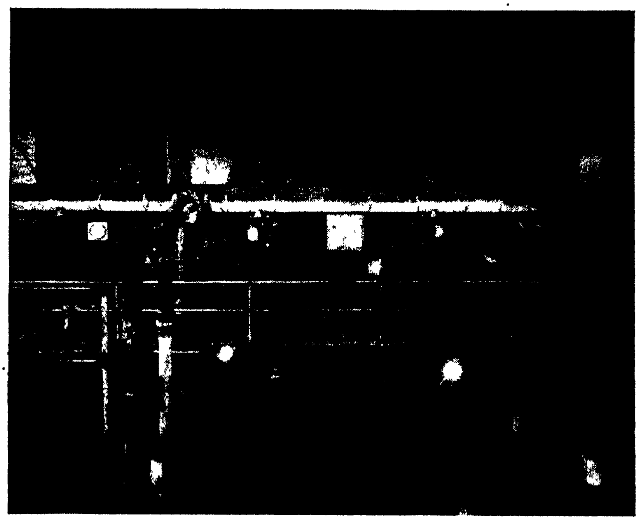


Fig. 96.—Battery of Steam Dryers. Johnson Fuel Co., Scranton, N. D.

Fig. 97.—Lignite Briquetting Plant of the Johnson Fuel Co., Scranton, N. D.

in this type of plant, the driving power is steam. After cooling, the briquettes are ready for the market and are shipped to consignees. It is certain that this fuel is well liked in the Dakotas. The capacity of the plant is at present understood to be 300 pounds per minute or 9 tons per hour.

In 1905 Ex-Senator W. D. Washburn erected a small plant for the briquetting of North Dakota lignite without binder, but the enterprise was never carried to commercial fruition.

Will the German brown-coal method ever be adopted on a large scale to American lignite production? It is possible. Exhaustive tests at the Bureau of Mines in Pittsburgh in 1908 indicate with a fair degree of clearness that deposits amenable to this treatment as practised in Germany are comparatively few. Certain North Dakota and Texas lignites registered absolute failures. Again, the method requiring a very large first cost and great power expense, as these machines do, carries a handicap against their adoption by American engineers. The shape and large size of briquettes are another handicap. None the less, in view of the success of the Johnson Fuel Company the engineers of the Fernholtz organization are working to widen the scope of the process beyond the lignite known to be peculiarly adaptable to this method, and one can not say that there will be little further done in German brown-coal methods in the United States.

II.—By Mixing with Binder and Briquetting by Coal Methods Modified.—The question arises then of the feasibility of briquetting lignites raw or dried with an addition of binder by the methods ordinarily employed for the briquetting of coal. A very considerable investigation and no little practical experience has been obtained along these lines. The fact that no plant is operating to-day successfully can hardly be called final, though, in view of experiences had, it is at least indicative.

Again, California led the way in pioneering the briquetting of lignite. In 1901 the San Francisco and San Joaquin Coal Co. erected a lignite briquetting plant at Stockton, California. The designer of this plant was Robert Schorr, one of the very well known briquetting engineers in the United States and particularly identified with pioneering the industry in California. The lignite used was comparatively old geologically, approached black

in color, and had a heating value of 11,000 B. t. u. In common with all lignites, it broke up in the fire before rendering its full quota of heat and slacked badly in the open air. It was found by experiment that the situation might be remedied by briquetting, and a plant was, accordingly, located at Stockton, thirty-five miles from the mines, as it was manifestly wiser (to avoid degradation) to haul the raw product this long distance rather than the briquettes. The entire product of the mine, as must be the case with lignites, was made into briquettes. The plant is known colloquially in the briquetting business as the Treadwell plant. J. H. Treadwell was the moving spirit in back of the enterprise.

The coal arriving at the plant was broken up in a No. 3 Williams crusher. In the early days the tendency was to crush too fine, and it was found that the best product was made by crushing to one-eighth inch size. From the crusher the coal was passed to the dryers, which were externally fired revolving cylinders 3½ feet in diameter and 20 feet long. The dryers were by-passed in the summer as the lignite dried out sufficiently in transit. From the dryer the material passed to a horizontal double-shaft pug mill 30 feet long by 36 inches diameter, steam jacketted. The steam jacket heated the coal sufficiently to insure a proper mix even if drying were not employed. In the pug mill the binder was added—asphaltic pitch made in the company's own still. The percentage of binder was between nine and ten. Coming from the pug mill the mixture was too hot for the press and was cooled by passing it outside the building over a series of conveyors. The briquettes were formed on two presses, both of Belgian type modified by Mr. Schorr. The capacity of the plant was 26 tons per hour of 7-ounce briquettes. It is said that the briquettes handled well and burned well. A significant point about the operation of this plant is that in perfecting the briquette bituminous coal yard screenings were added, the mixing taking place in the crusher. The screenings came from San Francisco, ninety miles away, and were evidently added to give the briquette "body" in the fire and the ability to hold together. It is unfortunate that this plant was destroyed by fire in 1905 and not rebuilt.

In 1904 the Bureau of Mines set up an experimental briquetting plant in St. Louis and conducted a long series of briquetting tests on the various fuels of the country, including most types of bituminous and anthracite coals as well as some of the lignites. The equipment at St. Louis consisted of a Belgian press, designated in the Bureau of Mines reports as the American Briquetting machine, and a revolver press (see Chapter II) designated in their reports as the English machine. The first lignite mentioned in these tests is a Montana black lignite from Red Lodge, Carbon County, Mont. Two runs were made on the English machine; the first with 16 per cent of very hard pitch. The briquettes resulting were porous and rough and, while reported as standing rough handling, were evidently not satisfactory. The second lot was briquetted with 7 per cent of melted pitch (about 200°) at high pressure and the briquettes were reported as brittle. A brown lignite from North Dakota was mixed with 12 per cent hard pitch without drying and briquetted on the English machine. The briquettes were poor and the repetition of the experiment with dried lignite gave nothing better. On the Belgian press the briquettes as turned out had a good polished appearance, but roughened almost immediately, scaled and went to pieces. A Texas lignite from Hoyt, Wood County, Texas, was briquetted in four lots containing respectively 5, 6, 7 and 8 per cent of coal tar pitch—all on the English machine and none satisfactorily. The Bureau of Mines attributed the poor results in this line of tests (as compared with the good results which they had with the same equipment on bituminous coals) to the fact that lignite, and especially dried lignite, picks up moisture extremely rapidly and in the presence of steam absorbs water far more rapidly than it takes up binder. With the equipment at hand it was impossible to control this condition. The sample of lignite from Wooters Station, Hulleston County, Texas, was tried in a laboratory hand press with coal tar pitch, asphalt pitch, resin, lime, various mixtures of these binders. All the briquettes so made were weak in the fire.

In 1914 J. A. Holmes, in charge of the St. Louis briquetting Station, sent to Germany samples of lignite from Lehigh, N. D., and Rockdale, Texas. It is reported that the briquettes made on the German presses at this time were successful and it is

especially interesting to note that a 2 per cent addition of coal tar pitch was made in at least a part of the shipment for work on the German machines. Notwithstanding the favorable nature of this report, it is significant that at Pittsburgh in 1908 where one of the German machines was installed, as hereinbefore mentioned, no additions of binder were made.

The year 1905 showed a great development in briquetting lignite in California. The following plants were established:

The American Ajax Briquetting Company erected a plant in San Francisco, using a special design plunger type of press. It had a capacity of 15 tons per day. The raw material was Coos Bay, Oregon, lignite, mixed with coal yard screenings, and the binder was an asphaltic pitch. The plant was destroyed by fire in 1906.

The Western Fuel Company of Oakland began operations in their briquetting plant the same year, the plant having been designed by Mr. Schorr. The plant was located on the water, and all coal was shipped in and unloaded from the boats. Thence it was fed to a Williams crusher, and from there to a dryer. In the dryer the coal was heated, and passed to a pug mill of Mr. Schorr's design. From there it was carried to a Schorr press. (See Chapter II). Briquettes were rectangular shape 2¾ inches x 1½ inches x 1⅞ inches. From the press the briquettes were carried by a short conveyor delivering to another one outside the bin. At the end of this conveyor they were sacked for the local market or taken to the storage bunkers. The binder here, as elsewhere in California, was asphaltic pitch. The average output was 8 tons per hour. In this plant coal yard screenings were added to the lignites. In fact, it is reported in 1915 that the Western Fuel Co. had briquetted several thousand tons of anthracite screenings in this plant.

At Pittsburgh, Cal., a briquetting plant was erected under the designs of Mr. Charles R. Allen. This plant was unique not only in the process but in the press used. (The Allen-Hutchinson press is described in Chapter II). The plant started by using the lignite produced by the Pittsburgh Coal Mining Co. at Summersville. During its later career more and more screenings from San Francisco were added to the mix. The binder was the usual asphalt pitch. The process was unique in that the mixture

of fuel and binder was passed through heating chambers in which the temperature was raised to a very unusual degree. A claim of Mr. Allen is that the mixture in this method becomes chemically changed, the binder entering into the body of the lignite and giving it a structure similar to bituminous coal. For such a mixture the press was peculiarly adapted. The briquettes were cylindrical, weighing 8 to 10 ounces each. This plant was destroyed by fire and subsequently not rebuilt.

Of all the Far West installations, one of the most interesting is that of the Arizona Copper Company, of Cliffton, Arizona. The material briquetted was a mixture of New Mexican black lignite and coke breeze from the metallurgical works. The mixture was 92 per cent of coal with 8 per cent of California asphaltic pitch. The capacity of the plant was 2½ tons per hour. The fines were fed from bins to a mixer where they were mixed with the pitch, which had been broken in a pitch cracker by the English system. (See Chapter X). From the mixer the flux was sent to a disintegrator pulverizing the coal and pitch into grains of 2 millimeter size. Thence it was sent to a heater and subjected to the action of live steam, giving the pitch sufficient liquidity to obtain the binding action. From here it was conveyed through a pug mill to the hopper of a revolver press, whence the formed briquettes came to an endless belt conveyor, which delivered the briquettes to the side of a railroad car in front of the building. The briquettes were rectangular in shape, weighing 4 pounds each. The plant operation was discontinued some years ago.

In Texas various companies negotiated for the erection of briquetting plants. The Eureka Briquette Company, of Rockdale, had its plant completed in 1907—but no persistent operation has occurred in that state.

In every one of these lignite operations the significant fact common to all is the addition of other forms of fuel to the dried lignite to obtain a good briquette. In some cases this addition is accounted for by the fact that the slack coal is obtained from time to time at prices cheaper than the lignite can be mined, but not in quantity sufficient to take the place of the lignite entirely. That such additi‹ n results in a beneficiation of the product cannot be denied.

The conclusion, in view of the above experiences, is that no method has as yet been found for the commercial briquetting of raw lignite, even if dried, by the addition of binder unless a quantity of other coal (bituminous, anthracite or coke) is at hand at a price sufficient to allow its admixture to the briquetting flux in quantity.

III.—By Carbonizing or Distilling Followed or Preceded by Briquetting.—It, is in fact, fairly well established that raw lignite—even when dried—is not good briquetting material, except, so far as North America is concerned, in unusual circumstances. Whether briquetted by the "Braunkohle" or the binder methods, such briquettes seldom stand weathering. In the fire, as soon as the glow point is reached, the light volatile matter distills out rapidly, causing the briquette to crumble long before combustion is fully consummated. Much material drops unburned to the ash pit, and the balance chokes the grate. The latest research in briquetting of lignites has brought most authorities to agree with Prof. E. J. Babcock, of the University of North Dakota, who says in *Bulletin No. 89* of the Bureau of Mines:

"After much investigation and many hundreds of tests, the writer has been convinced that the most satisfactory, if not the only successful, method of briquetting lignite, is to carbonize the raw lignite, so as to remove at least a large proportion of the volatile gases as well as the moisture. The residue, * * * * relieved of its excess of light gas, becomes excellent material of briquetting."

With the success of Braunkohle briquetting in Europe, but little attention has been paid to carbonizing lignites and the bulk of investigation has been done in this country.

The names most prominent in connection with this work has been:

E. J. Babcock, of the North Dakota School of Mines.

S. M. Darling, formerly with the Bureau of Mines.

Chas. O. Hoover, of Denver.

The Engineers of the Canadian Board of Lignite Utilization—Edgar Stansfield, being in charge of distillation research, and R. De L. French—Plant Engineer.

The first lignite carbonizing in the United States was done about 1885 at Camden, Arkansas, on the Lester variety of Arkansas lignite—material exceedingly rich in hydrocarbons.

The apparatus used consisted of a pair of iron pipes, closed at one end with gas outlet fitted in at the other. The pipes were fitted in a brick furnace, which, after the charge of lignite had been loaded in the pipes, was fired about 10 hours. Overnight the charge cooled. In the morning the carbon was raked out, and the tar collected along the take-off pipe. The gas was wasted. The carbon was mixed with the tar and some drying oil, and sold for cheap black paint. A larger plant followed, but was not continued in operation. A similar enterprise was undertaken at Poplar Bluffs, Missouri, some years later. No briquetting followed the retorting.

RESEARCH OF S. M. DARLING.

These attempts are interesting because they were followed about 1905, by S. M. Darling, who erected a small horizontal retort which carbonized 300 pounds lignite in 4 hours. The carbon here too was used as paint pigment. A year later a bench of four similar retorts were erected by Professor Darling and a test run to determine the gas quality of Arkansas lignites. The amount of carbon dioxide present—15.9 per cent—led to the rejection of this gas as low in illuminating power. As a power gas, or for illumination by Welsbach mantles it was well worth while.

This line of experiment demonstrated to Professor Darling the following:

(a) Carbonized lignite must be cooled, after distillation, without access of air. Dumped from the retort the char ignited immediately and quenching was extremely difficult.

(b) Lower temperature than usual to gas practice is to be preferred in lignite distillation. Thus a greater yield of liquid products, of higher pecuniary value, is obtained.

(c) A continuous process of retorting is desirable, and the fact that lignite crumbles during carbonization facilitates the design of such an installation.

(d) Because of the crumbling during carbonization, practically all the output of a lignite retort must be briquetted, especially if the product is desired for household purposes.

The next step in Professor Darling's work took place in Chicago. Here he set up an inclined, slowly rotating cylindrical retort, 1 foot, 2 inches in diameter and 15 feet long. The drum was heated by passing through a stationary combustion chamber. The material was fed at the upper end, and as it passed down the retort, encountered increasing temperatures until the maximum was reached at the discharge. The retort was self-feeding, its mechanism drawing the proper amount of lignite from an upper stationary feed hopper at each revolution. Here first the experimenting involved briquetting. A Belgian type press was erected, and a considerable tonnage of briquettes made.

The tar was distilled and the fractions determined. The difficulty with this oven lay in its rapid deterioration under high temperature and certain mechanical defects in operation. The three ovens consisted of vertical cast iron tubes, the lower portion being protected by fire clay tiles. As before, the maximum temperature was at the bottom and the feed and discharge was continuous.

As a result of the operation of this retort, the Saskatchewan Government commissioned Professor Darling to erect at Estevan, Saskatchewan, a small lignite carbonizing briquetting plant. This plant is reported in a special document written by Professor Darling and issued by the Government of Saskatchewan, entitled "The Carbonizing and Briquetting of Lignite."

In this plant the lignite was unloaded in cars to a bin, from which it passed to a crusher, was broken up, and distributed to the retort units. The retort may be described as a vertical chamber oven. It was operated on the coke oven principle, but advantage was taken of the breaking up of the lignite under heat to produce continuous loading and discharge. The discharge hopper, and in fact all the conveyors, elevators and bins handled the hot lignite, which was kept constantly in an atmosphere of exhaust steam. This oven was 8 feet x 9 feet 7 inches x 12 feet high. The lignite column was but 6 inches high. The capacity was 24 to 36 tons of raw lignite per 24 hours. The gas from the retorts was carried off by an exhauster, was washed and cooled, and after the ammonia was extracted, burned under the retorts. The temperature required was low; the gas was practically all distilled off at 1,000° F. The products were as follows:

1. Ten thousand cubic feet of gas (400 B. t. u. per cubic foot) serviceable for cooking or Welsbach mantle light. Six thousand cubic feet of gas required for retorts, 4,000 cubic feet surplus.

2. Oil or tar 15 gallons—light oils 11.5 per cent, carbolic oils and naphthaline 13.5 per cent, creosote oils 34.1 per cent, anthracene oils with paraffin 16.4 per cent, hard pitch 24.5 per cent.

3. Ammonia 15 pounds.

4. Lignite carbon 955 pounds.

The larger lumps obtained from the retorts of the lignite char were stated to be valuable for the gas producer, leaving the smaller sizes to be briquetted.

A large number of briquetting tests were made in various types of presses from the carbon obtained at the plant above described.

(a) In a Belgian press. The best briquettes made were bound with a binder of 8 per cent asphalt pitch and 2 per cent flour. These briquettes weighed 2 ounces each, and were called excellent. The test was repeated with 7 per cent coal tar pitch and 2 per cent flour with good results in a Belgian press owned by the Armstrong-Kerr Co., of Vancouver, the briquettes weighing 5 ounces each. At the Standard Briquette Fuel Company's plant, at Kansas City, Mo., an experimental run was made on the Komarek roll press (Figure 41, Chapter II), which was in the experimental stage at that time. Briquettes were made on this press with 8 per cent binder, without an admixture. The conclusion was reached at this time by Professor Darling that greater pressure than any roll press could give would be beneficial, and it was decided to experiment on various other presses. Samples were sent to Sutcliffe, Speakman & Co., Ltd., of Leigh, England. They mixed the coal with a binder consisting of 9 per cent soft coal tar together with an admixture of 15 per cent coking coal. The Emperor press used (see Chapter II) was capable of 10,000 pounds pressure per square inch, and gave a splendid briquette, rather too large for domestic purposes. A shipment was also made to the Chisholm, White Company, and briquetted on a White press in Chicago. (See Chapter II). This press gives a pressure of 5,000 pounds per square inch, and made a good briquette, cylindrical in shape, 3 inches in diameter, 2½ inches high, 14 ounces in weight, from 92 per cent carbonized lignite and 8 per cent coal tar pitch.

A run was also made upon a Mashek press, installed at the plant of the Northern Briquetting Co., at Minot, North Dakota. These briquettes were made of 83 per cent carbonized lignite, with a binder consisting of 8 per cent coal tar pitch and 2 per cent flour with an admixture of 7 per cent coking coal. These briquettes were hard and stood shipping quite well. Their weight was 2 ounces each.

At this writing it is planned by the Bureau of Mines to go forward with a plant in North Dakota for the carbonizing and briquetting of lignite from the ideas and special machinery of Professor Darling. The contract has been signed between the Bureau of Mines—John B. Adams, and Fred Bremier. It is expected that the work of this plant will result in duplications throughout the lignite areas. The co-operating company has agreed to provide a site and a sum of money for construction; to furnish the coal and raw material and conduct the business operation, including the selling, and to furnish labor.

In this plant pillow-shaped briquettes will be made, by mixing lignite (not charred), dried in a rotary dryer or similar apparatus, with eight to ten parts of pitch, and briquetting the mix on a roll press according to the latest improved practice. The briquettes will then be passed to the retort, which consists essentially of a plurality of inclined retort members, set in a furnace so arranged that the furnace gases, passing over baffles, completely envelop the upper or charging end of the retort. The lower half of the retort members are enclosed in a cooling chamber, so that the briquettes after distillation are cool enough to pass out of the retort directly into the cars. Means are provided for the collecting of the tars and gases, as in all distillation practice.

RESEARCH OE E. J. BABCOCK.

Professor E. J. Babcock, Dean of the North Dakota School of Mines has been associated with lignite investigation for many years. In 1909 the first work of Professor Babcock consisted of research in the production of gas and by-products from lignite coal. Here it was proved that the gas from the different kinds of lignite was very similar and could be removed at the same temperature, and that there was much similarity in the residues as well. A cast iron retort was built to form a small gas bench, which retort had a capacity of but 40 pounds lignite. The equip-

ment for extraction was complete, and special arrangements were made for scrubbing and purifying the gas. The tests at this experimental plant, which was located at the University of North Dakota—Grand Forge—led to the installation of a larger plant for both carbonizing and briquetting at Hebron, North Dakota, a station of the Bureau of Mines.

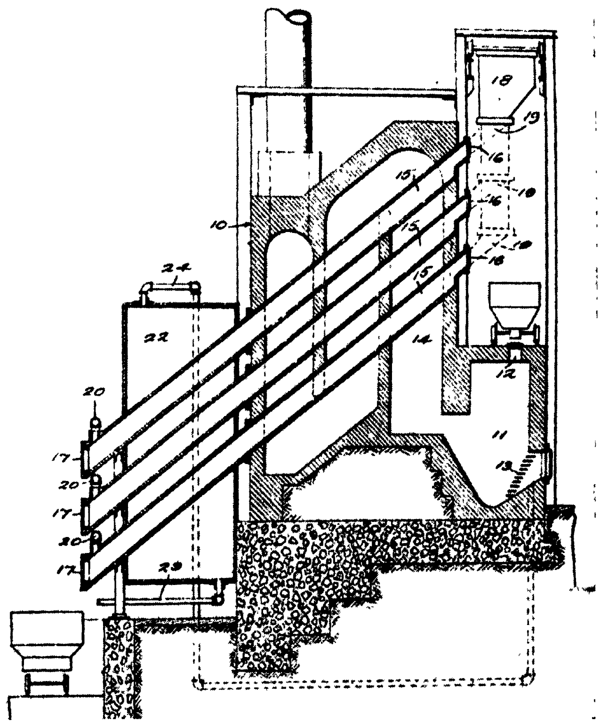


Fig. 98.—Darling Retort for Carbonizing Lignite Briquettes.

The equipment consists of a large experimental gas plant as follows: Gas bench 11 x $6\,^1/_2$ x $7\,^2/_8$ feet. Clay retort $1\,^1/_4$ x $2\,^1/_6$ x 9 feet, 4 inches thick. Capacity 400 pounds coal in 4 hours.

Bridge wall 9 inches thick for distributing gases. The chimney at the back of the bench with steel stack 15 feet high.

Hydraulic main water tube condenser for removing tar, coke, dust and pitch. Two cylindrical tower scrubbers. One purifier. One cylindrical box 4 feet in diameter x 2½ feet deep, containing trays of purifying material. One meter, one gas holder.

Early developments in the experimental plant showed that it was necessary to dry the lignite before retorting. Accordingly, Professor Babcock recommends a rotary dryer of standard type as a preliminary to the carbonization. A comparison of retort testing of lignite and bituminous coal showed that lignite lost its gas in half the time required for gas removal from bituminous coal, and the temperature was 1,270° F. for lignite as against 1,655° F. for bituminous coal.

Throughout, tests indicated that the principles used in the manufacture of illuminating gas and coke may be used—properly modified—for lignite. It was found, however, by Professor Babcock, as well as by Professor Darling, that lignite residue was of little value in the form in which it was discharged in the retorts, but required briquetting.

As a result of these experiments Professor Babcock advocates either the inclined or vertical retort, which seems to be common ground with Professor Darling.

Fig. 99.—Carbonized Lignite Briquettes after Exposure to Air for Six Months. Made on a Mashek Press at the Hebron, N. D. Plant.

The briquetting plant at Hebron consists of a disintegrator, which breaks all lumps of residue to one-fourth inch size and less, followed by a set of rolls, which reduces still further the sizes of the raw material. Thence the crushed lignite is carried to a bin at the base of which an automatic feeder correctly pro-

portions the residue for delivering to the mixer. In the mixer the binder is added and a quantity of bituminous coal screenings. One or 2 per cent of flour is added to the admixture to assist the binding quality. Heat is applied to the mixer which is of the usual pug mill type. The pug mill is divided into two sections. In one drying, mixing the lignite char, bituminous coal and flour is completed. At right angles and below is located the wet mixer which mixes up the pitch binder with the dry mass. The proper quantity of pitch is delivered by a rotary meter introduced into the mixer in a spray with steam. On the way to the press the mixture is cooled to the proper consistency and is dropped into the hopper of a rotary Belgian press—Mashek type. This machine delivers the briquettes to a conveying belt, which carries them into storage bins.

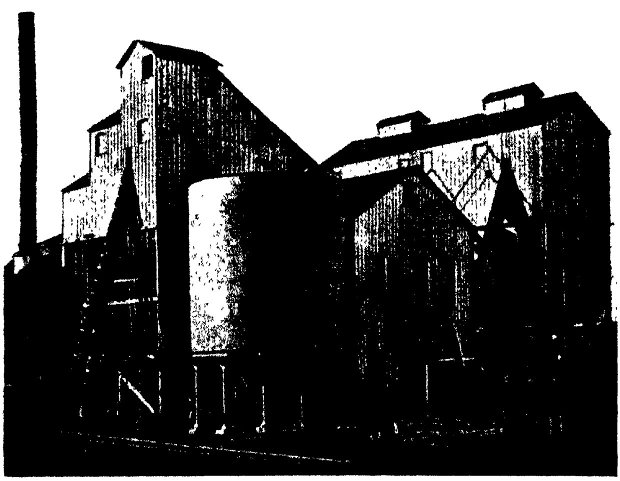


Fig. 100.—Lignite Briquetting Plant of the Northern Briquette Co., Minot, N. D. Designed by C. J. Mashek.

As a result of the experiments conducted at the Hebron station, the Northern Briquette Company was organized and constructed a carbonized lignite plant at Minot, North Dakota. This plant was built in 1913, under the direction of Professor Babcock,

who specialized on the by-products end, and G. J. Mashek of the Mashek Engineering Company, New York, who designed and installed the briquetting equipment. A very serious effort was made to carbonize the lignite in beehive ovens, modified from the bituminous coal design in accord with the peculiarities of lignite. It was presumed that this method of carbonization would be so inexpensive as to justify the loss of by-products. In the battery the base of each oven was about 10 feet in diameter, and the peak of the hive about 8 feet high. Each oven had a capacity of 12 tons of lignite. Ignition started from the heat on the floor and sides of the oven left from the last charge and carbonization went on without further attention over a period of two to three days. The charge was then raked out, quenched and another charge substituted. The results showed in addition to the non-recovery of by-products or gas that 15 per cent of fixed carbon was consumed, with a consequent increase in the percentage of ash in the briquette. As a consequence it is understood to be the intention of the company to substitute a commercial by-product plant for the beehive ovens.

The briquetting equipment in the Minot plant consists of a series of mixers with means of introducing a percentage of bituminous coal and anthracite screenings, when obtainable, in varied quantities. The binder is melted in the usual way, and consists of a mixture of coal tar pitch and asphaltum. The coals and pitches thoroughly admixed are fed directly to the Mashek press, and thence over a cooling table to the briquette bins. This plant had some success at first, but it is understood not to be operating at present. Professor Babcock has continued his work at Hebron. At the present time his recommendations call for the winning of all tar and gas from lignite. It is found in the process of gas manufacture that 15 pounds of tar are obtained from one ton of dry lignite, which, added to the briquette mixture would cut down the necessary pitch admixture to 4 per cent. Professor Babcock has made excellent briquettes, using lignite residue with 5 to 6 per cent of pitch, 5 per cent of bituminous coal and 1 to 2 per cent of flour or grain screenings. Abrasion and crushing tests of such tests are herewith shown:

TABLE XIII.

RESULTS OF COMPARATIVE ABRASION AND CRUSHING TESTS OF VARIOUS KINDS OF COAL AND OF LIGNITE BRIQUETTES

Sample No.	Kind of coal	Proportion larger than 1-in. size remaining after abrasive tests	Crushing strength per square inch
		Per cent	Pounds
1	Anthracite	98.50	3,950
2	Kentucky lump	93.43	1,970
3	Youghiogheny	81.20	3,680
4	Youghiogheny	86.65	1,510
5	Pocahontas	75.75	1,556
6	Lignite briquettes	99.60	1,810
7	Lignite briquettes	97.75	1,370
8	Lignite briquettes	99.38	1,530
9	Lignite briqnettes	99.23	1,825

Results represent averages of three tests (*Bull. 89*, U. S, Bureau of Mines)

It was also proven that these briquettes stood dropping with less breakage than the raw bituminous coals mentioned in the table, and were highly resistant to weather conditions. Exposed for one year to all manner of climatic conditions they were still good fuel for the furnace. In the fire, consumption is practically 100 per cent and they stand intense furnace heat without disintegration.

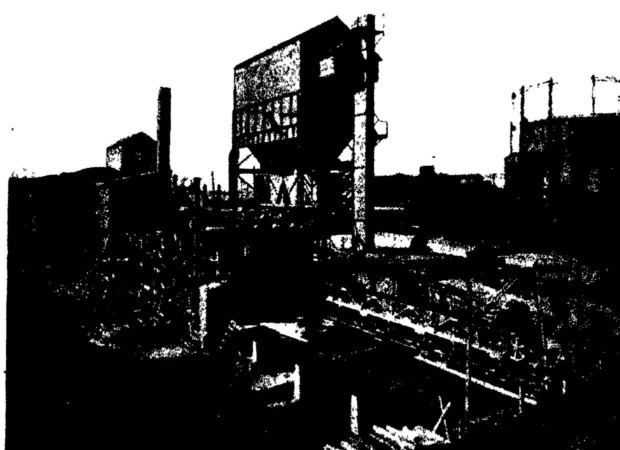


Fig. 101.—Lignite Distilling and Briquetting Plant. American Coal By-Products Co., Denver, Col.

RESEARCH OF CHAS. O. HOOVER.

The work of Mr. Charles Hoover in Denver consisted of applying the oven principle to lignite distillation, with the subsequent briquetting of the lignite char by the standard coal briquetting methods. After a long series of investigation a plant was established in Denver under the auspices of the American Coal Refining Company during 1915. The coal was a Colorado lignite, of high quality as compared with the Dakota and Texas lignites already mentioned, and on a par with the Ione lignites of California. The analysis is as follows:

Moisture	12 01	Per cent.
Vol. matter	29.19	"
Fixed carbon	55.00	"
B. t. u. per pound	9935	

The oven installation at this plant consisted of four parallel ovens in battery. Each oven was 36 feet long, 9 feet high and 18 inches wide, lined with refractory brick. Within the oven were horizontal longitudinal flues, carrying hot gases from the burners, located at one end. Passing through the flues the gases were carried through the boilers of the power plant. In addition, a series of flues carried fuel gas through the floors of the ovens into the mass of baking char, in this way enriching the gas product of the operation. The ovens were sealed tight. The temperature maximum was 500° C, and the distillation period was two hours. The products were 10,000 cubic feet of gas, 13 gallons of tar, and 2½ pounds of ammonium sulphate per ton of charge. The distilled gases were carried by an exhauster through scrubbers and condensers to the final treatment, that of electrical precipitation, carried on by means of a pipe carrying piano wire electrodes operated at a current of 60,000 volts. The gas, thoroughly cleaned, was carried to a gasometer. From the gasometer it was returned by an exhauster to the plant as needed. The surplus was sold.

The tar was sent to a still of 20 tons capacity, and divided into light oils, creosote and hard pitch. The char in the ovens was removed by an electrically operated discharger which pulled out the residue and dropped it into an iron screw conveyor, where it was quenched by water. All coal fed to the ovens was first crushed in a 24-inch roll crusher, breaking to 1-inch sizes. After the distillation the char was screened in one-half inch and one-

fourth inch mesh trommels. The oversize was reduced in a ball-mill and joined the other screened products in a flight conveyor to the storage bins.

All materials prior to the briquetting operation were passed over a magnetic pulley and then sent to a revolving pre-heater, heated by super-heated steam. From the pre-heater the ingredients went to the mixer. The mixer was the usual pug-mill, 18 feet long, 4 feet wide, with three longitudinal shafts carrying mixing arms, and steam jacketted, except at the end of the mixing operation, where the last jacket contained air for cooling. Melted pitch was added to the dry materials in this mixer. The melted pitch was delivered from a tank under pressure by compressed air, which forced the melted pitch through the mixer feed. The mixed flux was carried a considerable distance in a flight conveyor, enclosed, into which compressed air was fed for the purpose of further cooling. From here it passed directly to the press and the "carbonets" were made at the rate of 25 tons per hour, each briquette weighing 3 ounces. They were sprayed by water, screened and carried to the storage pile.

The briquettes produced had the following analysis:

Moisture	1.34	Per cent.
Volatile matter	7.60	"
Fixed carbon	84.04	"
Ash	7.02	"
B. t. u. per pound	14061	

This plant operated for about two years, when it was taken over by the Denver Coal By-Products Company, who installed the Green-Laucks system of retorting bituminous coal. It became an essentially bituminous coal by-products plant under this process, and briquetting was abandoned. The coke was produced from the bituminous coals of Colorado in large enough sizes to preclude the necessity of briquetting. Under these conditions a plant is operating to-day. How the Hoover process would work on the Saskatchewan, Dakota or Texas lignites does not appear to be known.

RESEARCH OF THE LIGNITE UTILIZATION BOARD OF CANADA.

Following the work of Dr. Darling in Saskatchewan, the Lignite Utilization Board was formed in November, 1919, by an order in Council of the Dominion Government. Mr. R. A. Ross was appointed Chairman. A series of investigations were held under the auspices of the Board at their laboratory in Ottawa.

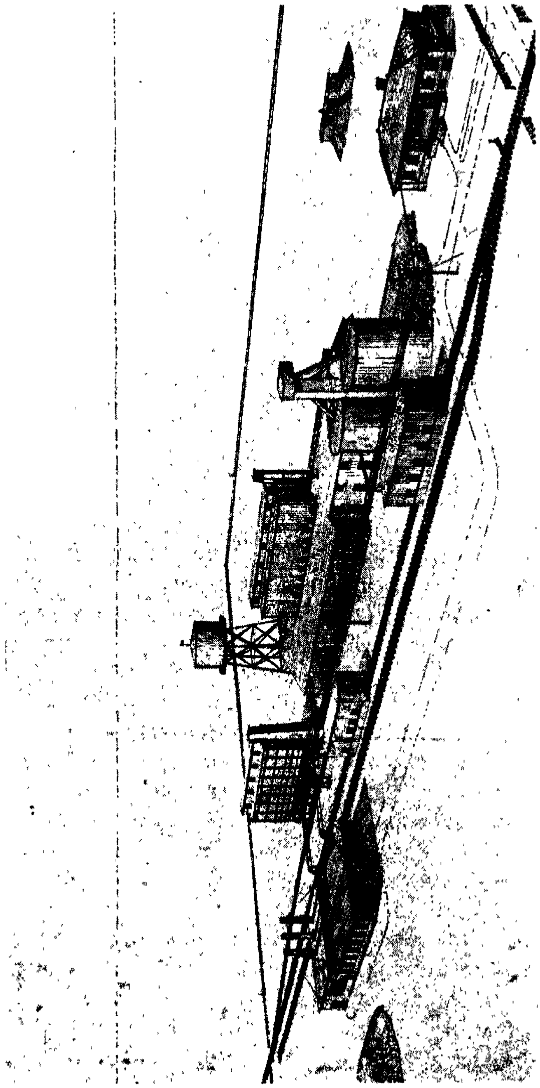


Fig. 102.—Experimental Carbonizing and Briquetting Plant near Bienfait, Sask.

The most active in this investigation were Messrs. R. De L. French and Edgar Stansfield, the former being concerned with the engineering features of the problem, and the latter with the chemical. Months were spent in analyzing all methods of carbonizing and briquetting coals. After studying the relative wearing, steaming and burning qualities of all the various kinds of lignite briquettes, and after investigating the problems of pulverization, gas production and others, it was determined to locate a plant of commercial size at Bienfait, Saskatchewan. On all the evidence submitted, it was evident that the only method adaptable to the Canadian lignite problem was distillation of the lignite followed by briquetting. During the course of their investigations, large samples were sent to the General Briquetting Company in New York, who had a thorough test of the material made from the by-product point of view, followed with a series of briquetting tests under the Dutch process. The distillation was done in the testing plants of the Fuel Products Company in Hoboken, N. J., and the briquetting at the plant of the General Briquetting Company in New York. The report of the run made by the Fuel Products Corporation on by-product test gives an excellent idea of the character of the lignite with which the Board was confronted for the making of domestic fuel for Central West Canada. The retort used in Hoboken was the Pritchard type, illustrated in Figure 153 (Chapter XV), consisting of a vertical cylinder with sloping sides—the retort proper—a series of pipe lines, condensers and containers. In the line is placed an exhauster, and the pipe line is so arranged that a portion of the gas is returned to the retort. This arrangement maintains a continuous circulation throughout the system with relaxed vapor tension in the retort. This system is the invention of Thomas Pritchard, of New York. Characteristic results were obtained from this lignite at this run. The report of the run is shown in Table XIV.

Although by-products production presented an interesting possibility, the main idea of the Board was to produce a good domestic fuel. It has been decided this end would be best accomplished by very rapid carbonization, the charge being submitted for a short interval to a temperature of 2,500° F. This temperature, operating for a short space of time, produces a char very similar

TABLE XIV.

BY-PRODUCTS TEST ON CANADIAN LIGNITE

Weight of charge	297 lbs.
Duration of run	9½ hours
Maximum temperature	540° C (1,004° F.)
Surplus gas produced	5,180 cubic feet per ton
Yield coke { 50.48% / 150 lbs.	(1,009.5 lbs. per ton)
Oils	5.14 lbs. per ton
Aqueous distillate	605.7 lbs. per ton
Oil distillation test on 249 gm. sample water	64.0 gm.—25.6%
Oil layer over with water (to 180° C.)	11.0 "
1st fraction 180° - 260°	12.5 "
2nd " 260° - 300°	27.5 "
3rd " 300° - 330°	36.0 "
4th " 330° - 350°	20.0 "
5th " 350° - 365°	23.5 "
Residue (fluid enough to pour)	20.0 "
" (solid in flask)	22.0 "
	236.5 gm.
Loss	12.5 " —5%

Second and third fractions had yellow crystals contained in it.
Trace of phenols in first fraction.

to that produced under low temperature conditions, operating for longer periods. Presumably the by-products produced are affected to their detriment by the high temperature, but this end of the operation is considered of secondary importance. It was desirable that the carbonization proceed as rapidly and as thoroughly as possible, having in mind the necessity for high quality char, even though the by-product production be lowered in consequence. It seemed highly desirable that the process of carbonization be continuous and the attainment of this desire was assisted by the quality of the lignite, which at no time becomes sticky in the course of distillation.

The retort consists essentially of an enclosed surface, in batteries of three each, inclined at an angle slightly greater than the angle of repose of the crushed lignite (45°). The material is charged in at the top from a hopper, so constructed as to give an even flow, and passes over a succession of baffle plates inserted to control the thickness of the material. Each baffle forms, with the sides and sloping bottom of the retort, a recess, which fills with carbonizing lignite as the recess below is filled; and discharges into the next lower recess as that recess is emptied. A mechanism at the bottom of the retort regulates the discharge,

which in turn regulates the rate of flow. The gas off-take is in the cover. The material is kept stirred by its passage under the baffles. The surface is heated by the lignite gas burned under it.

Following the distillation of the lignite, in which the fuel is disintegrated to an extremely fine size, 2-ounce briquettes are made by standard methods, incorporating, however, the very best practice and the latest discoveries. From the retort the char goes directly to a 12-foot paddle mixer of the usual type, in which about 10 per cent of coal tar pitch is introduced. From this mixer the mass is carried downward through a steam fluxer and thence is delivered to an 8-foot masticator (see Chapter X). It will be seen that the Dutch process of fuel briquetting has been adopted at this plant or, at least, is under serious test. The discharge is through the center bottom of the masticator pan. The material goes through another mixer set at right angles to the first, the paddles of which serve to break up any cakes that may have been formed during the heavy mastication; thence it is carried by elevator to a Belgian press and formed into eggette briquettes. The briquettes are screened and carried along a cooling conveyor to the storage bin. It is believed that the fuel will under-sell coal in the Saskatchewan market, and $12.00 per ton delivered is the price mentioned in 1922 as compared with $18.00 for anthracite.

It is seen that the tendency for lignite utilization, at least in North America, is along the lines involving distillation with winning of the by-products and briquetting. Whether the briquetting will come first, followed by distillation, or the distillation precede the briquetting of char, is a matter for future practice to decide. Present practice tends toward the latter procedure. Certain it is that in the lignites as well as in the bituminous coals the whole modern tendency is to educt the volatile products in high value form, making a superior fuel of residual char.

In Germany, a recent process has been reported (Halbkoks Process) whereby a proportion of lignite char is mixed hot, as it comes from the by-product ovens, with wet raw lignite, and the mixture briquetted. This proce s has not as yet been widely adopted but is regarded as having interesting possibilities.

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CHAPTER X.

PRINCIPLES OF BRIQUETTING WITH BINDERS. THE BRIQUETTING OF COALS. COMBUSTION OF FUEL BRIQUETTES.

Most substances that require briquetting in order that their usefulness be enhanced require a binder. The principles involving the mixing of the binding material with the finely divided solid, whereby is attained the highest possible homogeneity of the final product, are of importance at least as great as the correct choice of press. The briquetting of coal fines stands out as preeminently the branch of the industry wherein these principles have application. From the study of coal briquetting we have obtained the closest acquaintance with these principles. Hence, a discussion of the fundamentals of coal briquetting with the binders adapted to it, is, within limits, a discussion of the briquetting of all fine materials not capable of supplying their own binding means in whole or part.

To start, then, we have a substance, as for instance coal, incapable of satisfactory briquetting without binding means, and a binder selected from the list in Chapter VI, usually some form of pitch. Our problem is:

1.—Unless the binder costs as little as or less than the coal, and is of equal fuel value, (a by no means normal condition), the design should involve as little binder in the briquette as possible. Speaking broadly, the more mechanical and thermal treatment given the coal-binder mixture, the more efficient binding work done by each particle of binder, and hence less is required.

2.—To bring to the press a coal-binder mixture that is best adapted to the press chosen. The mix should have the proper consistency—not too dry, not too soggy—should have the proper temperature—too hot or too cold is fatal to success.

3.—To install that type of press best suited to market conditions; *i. e.*, to make a briquette of the shape and size demanded by the consumer.

4.—To so treat and handle the briquettes after pressing, as to make them fulfill the requirements of the market. This treatment would vary from simple cooling—all that is required by the pitch- or oil-bound briquettes—to baking or carbonizing, followed by cooling, necessary when organic, water-soluble binders are used.

COAL BRIQUETTE STANDARDS

The highest standards for coal briquette excellence are in the North Eastern United States, where the people are accustomed to burning domestic sizes of anthracite. Fuel briquettes in this locality must conform to the following standards—

(*a*).—They must be tough—stand handling as well as anthracite coal (stove size)—which means that they must stand shipment by train, followed by lighter to barge, barge to bin, bin to wagon, wagon to cellar—all with less than 15 per cent degradation.

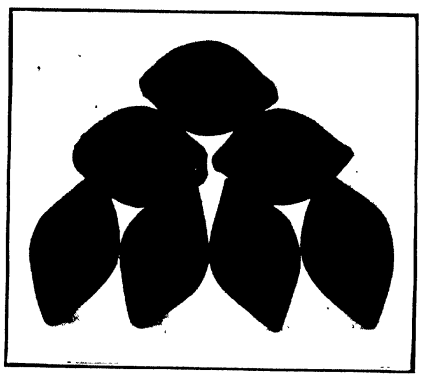

Fig. 103.—Typical 2-ounce Anthracite Briquettes. (Product of Universal Press).

(*b*).—They must be waterproof and weatherproof. The usual test is to leave a load in the open weather for a year—and the briquettes should be fit for the fire at the end. Many authorities consider this test too severe. It is obvious, however, that briquettes must be able to stand up during seven months of hot and cold weather under damp cellar conditions.

(*c*).—They must be smokeless and sootless, or nearly so. The further one travels from the anthracite fields, the less the importance of this restriction, at least so far as marketing is concerned. In the crowded sections east of the Allegheny Mountains, however, neglect of this phase of the subject spells failure. Westward, bituminous coals are burned in the households, and the people understand how to handle the smoke nuisance.

(*d*).—They must hold together in the fire until consumed. This is, primarily, a binder efficiency question. When briquettes are burned, the binder cokes, and upon the strength and fire resistance of that coke depends the consistency of the burning briquette (see Chapter VI). If the binder coke is consumed before the fuel itself, a stream of finely divided unburned material passes through the grate—incidentally choking off the draft—showing later an undesirable percentage of unconsumed carbon in the ash. To avoid such a condition, the briquetting engineer either cokes his binder before selling his briquettes or selects a

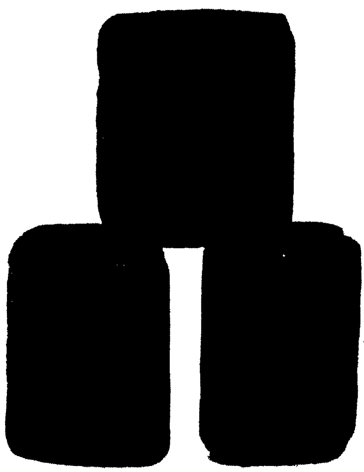

Fig. 104.—Two Ounce Pocohontas Coal Briquettes Made by the Berwind Fuel Co., Superior, Wis.

binder of highest coke-producing quality, and in both cases, arranges his mixing and pressing to obtain the thinnest possible binder film between the coal particles in the briquette. The more efficient the mixing and the higher the pressure (within limits), the thinner that film; and the thinner the film, so produced, the tougher and more fire resistant the binder coke.

So important is this feature in the case of anthracite briquettes that a percentage of coking soft coal (up to 10 per cent total bri-

quette material) is often added, whose coke, formed during briquette combustion, very efficiently stiffens the binder coke. No appreciable increase in smoke results from this practice. In fact, where briquettes are made from bituminous coal—without hard coal screenings—the briquettes produce smoke only on ignition, and then far less than do the prepared sizes of the coal from which they were made.

It should be noted, too, that most binders are practically ashless; so, even where their consumption is simultaneous with that of the fine fuel, the bond that existed terminates with their destruction, and the briquette disintegrates into fine particles of 95 to 100 per cent ash. Arrangements must always be made to dispose of this ash, by traveling grates, shakers, blowers, or efficiency in combustion.

(*e*).—They should approach, as nearly as possible, 100 per cent combustion.

If briquettes fulfill the requirement of standing up in the fire—there is little difficulty about their attaining a nearly complete combustion. Well made fuel briquettes are, invariably, more efficient in combustion than the screened fuel equi-size with them.

(*f*).—They should not clinker.

It is plain that in fuel briquettes, where each particle of coal is surrounded by a film of binder or (while combustion is under way) of binder coke, of a different chemical nature, the fusion of ash is much retarded. This retardation is assisted, too, by the porosity of the briquette, undoubtedly of increased importance in the carbonized product. Unless mineral binders are used containing alkali silicates (which, manifestly, would lower the fusion point of the ash to an uncomfortable point) it may be said that, for all practical purposes, all well made briquettes are clinkerless.

(*g*).— The heat value must be at least equal to the fuel from which they are made.

Under this restriction, the manufacturer hesitates to use mineral binders, for they add to the ash content. On the contrary, he is interested in obtaining a raw material as low in non-combustible as possible. Pains are taken to dry the coal carefully, and to see that as little water as possible—whether by steam condensation,

consistency improving, or cooling spray—is used in the course of manufacture. In practice, briquettes have higher B. t. u. than the coal from which they are made, due to comparative freedom from water, and the presence—usually—of high heat value oils or pitch.

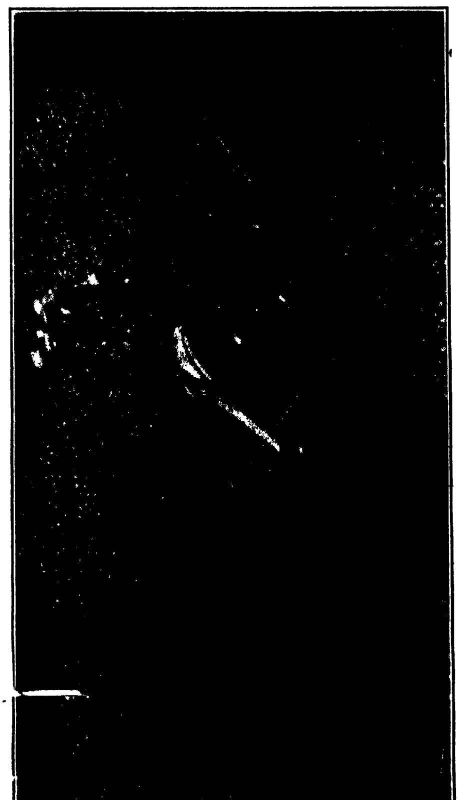

Fig. 105.—Rough Handling for Briquettes. "Boulets" of the Lehigh Coal and Navigation Company are handled with Clam Shell Buckets at the Brooklyn Union Coal Co. Yard, Brooklyn, N. Y.

(*h*).—The briquettes must be produced at a cost that enables their sale, at a considerable discount under the price of hard coal in the locality reached by the briquette plant. Anthracite briquettes sell for less than anthracite coal of the equivalent size.

Bituminous coal briquettes, on the other hand, are sold at a premium over the price of sized bituminous coal of equivalent size.

Summarized, therefore, the manufacturer must make briquettes that are tough, resisting degradation under rough handling; well bonded—holding together in the fire until consumed; kindling easily, but burning well; and giving 90 per cent combustion accompanied by adequate heat, with capability of holding the fire overnight; not clinkering, but, on the contrary, giving the minimum of ash nuisance; having smoke and soot either absent or reduced to a non-irritating minimum; and, withal, low in price—such is the product aimed for.

If it be mineral for smelting or a metal to be melted that requires a bond—the requirements are parallel to the foregoing. Toughness and ability to take punishment are always prime requisites for any briquettes. Ores, briquetted with binders, going through the blast, are subjected to high heat, abrasion and pressure simultaneously, and it is generally necessary that the briquette form be held until the values are extracted, for disintegration means total loss. Low cost of manufacture is an absolute essential. Valueless adulterants, moisture, and flux consuming elements are not desirable.

In all instances a minimum of binder is desirable. In all instances that minimum may be secured by obtaining homogeneous mixture at the proper temperature. Reconciling the proper amount of processing to the proper proportion of binder and fine material is the engineer's task.

COMBUSTION OF FUEL BRIQUETTES.

Fuel briquettes have been used for heat raising under practically all conditions to which the carbonaceous matter, from which they have been made, has been applied. These uses are diverse, and include both domestic heating and industrial power raising. As briquettes are seldom less than one ounce in weight, there are few instances in the latter function where they can compete successfully with small sizes of anthracite coal or caking bituminous slack. However, small coal sizes seldom enter the domestic heating field, and the possibility of the use of briquettes therein is but little restricted. In the power field briquettes have a wide application, and have especially found a place on steam

locomotives. In stationary practice the combustion of briquettes requires the presence of shaking grates, or failing that, blowers. Where briquettes are burned on stationary grates without the assistance of blowers, the fine ash made in burning tends to clog up the spaces between the grate bars, the draft is cut down, and heat falls. Under such conditions slicing is necessary and not always advantageous.

Briquettes burn in practically all cases progressively from the outside inward. As the volatile matter is driven off coke is formed, which burns to ash in layers. Gradually the ash falls away through the grate in fine particles. The harder and more dense the briquette, the less easily it burns.

As stated elsewhere briquettes are either made in large sizes, on piston and mold or Rutledge presses; or, in shoveling sizes, made on roll, or in some instances, on open-mold presses.

At the Berwind Fuel Company's plant, Superior, Wisconsin, the large Pocahontas briquettes, made of Pocahontas coal, are recommended for furnaces and heating plants with large fire pots, and for fire places; while the small briquette is best adapted for cook-stoves and heating plants with small fire pots.

In Germany the shoveling sizes are not used to nearly so great an extent as are the larger sizes. These are made in large quantities from braunkohle as outlined in Chapter IX, and to a far smaller degree from other coal mixtures—a binder being used. They are especially adaptable for housewarming in the tile stoves —a heating medium that has had but little vogue in this country. A few large briquettes burning in these stoves give a good heat for a long time. Very generally are they used as well in grates and cooking ranges. The sale of soft coal briquettes in Western Germany has been for many years controlled by the Briquette Sale Syndicate of Dortmund, controlling most of the factories in the Rhine provinces. When burned whole they consume very slowly, giving out a steady and moderate heat. When it is desired to intensify the heat production, they are broken up, and this practice is usual where the briquettes are used in the industries. The Prussian railways have used these briquettes for a great many years, either burning them alone or mixing them with the soft coal—the latter being considered the better practice.

In England briquettes are generally designated as "patent fuel" and an enormous industry has sprung up, especially centered in the vicinity of Swansea and Cardiff in Wales. The small shoveling briquette, made on the roll press, has but recently made headway in the British Isles. The business has been largely export, and the favorite product produced has been a large brick, which is capable of being stowed in ship bunkers with greatest economy of space, although the labor cost is considerable.

South America imports a large tonnage of British briquettes, which are burned on locomotives. The firemen, wherever such briquettes are used, have to break them up with a slice bar and throw them into the fire box. Such practice, universal on German, French and South American railroads, could not be introduced in the United States, either on railroads or in homes, as can readily be imagined. In consequence, there has been little attempt and no success in introducing the large size fuel brick in this country. In the homes in the United States a central heating plant is rather more usual than stoves in each room, as in Europe. Therefore, again, the demand would call for the shoveling size.

Usually very little effort is necessary to obtain trial and introductory orders of briquettes for household purposes. It is very important that the purchasers obtain the necessary instructions in the proper method of firing and burning. Unless the briquettes have been carbonized, there is a smoke given off at the first firing which, of little offense in the case of asphalt bound briquettes, but heavy, black and sooty where coal tar binders are used, belongs in the chimney and not in the living rooms, exactly as is the case with invisible though sometimes obnoxious gases of the anthracite coal combustion. In burning briquettes, immediately after firing, all drafts should be open until the combustion is fairly started, then the lower draft should be shut off to some extent, to avoid too hot a fire, and consequent rapid exhaustion of the fuel. Briquettes make a far more intense heat than anthracite coal if fired in the same way, but it is easy to acquire the knack of burning them economically. As their bulk is greater than similarly sized coal, it sometimes seems as though they are burning much faster than anthracite, but it is more the seeming than the reality. Certainly, at a lower price

they are a far more economical fuel. In the kitchen range, in heating stoves in rooms, or in open fires, there is ample testimony to the effect that the briquette fire is superior to anything now available. In furnace work for a heating system, great care must be taken not to overload the grates. When they are so overloaded, the briquettes lose a large proportion of their heating value in the form of a smoke that ought to be consumed. Only a gentle shaking is necessary at night, as the ash is extremely fine and drops readily without even a suggestion of a clinker. It must be pointed out carefully, however, that briquettes made with asphalt or pitch must not be touched during the first period of burning. Just after the heat strikes them they become softened, and will break into dust if struck with a poker. As soon as red hot they are intensely hard, and it pays to rake them over slightly on the top before shaking and re-firing.

A great deal of unofficial experimenting has been done—practically none in a scientific manner—on the effect of mixing coal and briquettes and burning the mixture in domestic heating appliances. The evidence at hand shows fairly conclusively that such a mixture gives better fuel economy than does either of its components burned alone. In personal experience the writer has found that a mixture consisting of 75 per cent of coal briquettes and 25 per cent egg coal lasted about 25 per cent longer than did the coal when burned alone, and about 15 per cent longer than when the briquettes were burned alone—this in a medium sized house-heating hot air furnace. In Brooklyn where large quantities of the Lehigh Coal and Navigation Company's briquettes are purchased by small householders in one and two ton lots, mixing of the two fuels in some form or other is very widely practiced. The stove coal, stronger during combustion than can any briquette possibly be, seems to give good body to the fire bed and prevents too rapid combustion; the briquettes, on the other hand, serve to raise the actual fire temperature higher and insure a more complete combustion of the coal admixture. When one considers that the average unconsumed carbon content of the ashes of the City of New York runs between 30 and 40 per cent, and that mixtures of briquettes and coal seldom show a residual carbon of more than 15 per cent, the advantage is obvious.

Just as obvious is the probability of a wide future for briquetting in the anthracite districts. It is predicted that following a series of tests, in which the improvement of stove coal by 10 per cent to 25 per cent briquette admixture is clearly proved, that the anthracite operators will take action. An announcement will be made preparing the public, and thereafter stove coal will probably contain as high as 25 per cent briquetted culm. Provided the culm is properly washed before briquetting, the stove coal shipped in this condition will be superior to the product previously marketed. To-day, when egg size and pea are in abundance, the stove size remains short, and such a method for increasing the quantity of stove coal available, at the same time shortening the demand by an amount proportionate to the economy the mixture attains, would result in making the public demand for egg, nut and pea on a par with that of stove. Such a course, affording an answer as it does, to one of the most vexed problems in anthracite marketing (namely the maintenance of a balanced market for all sizes), is so simple that the anthracite operators could hardly afford to ignore it for long. Briquette machinery should be an integral part of every coal breaker, and the briquettes should be mixed and sold with the stove size coal.

Briquettes carbonized do not make smoke, nor must care be taken during the first period of burning. There is no melting of binder in such briquettes.

In 1911 the Bureau of Mines published *Bulletin 27*, which included the report by D. T. Randall on an exhaustive series of tests on coal and briquettes as a fuel for house-heating boilers. These tests were made partly at St. Louis, Mo., and partly at Urbana, Ill., and covered a series of briquetted Indiana, Missouri, Illinois, Pennsylvania, and other coals. Anthracite coal was run as a check, but no tests appeared to have been made on anthracite briquettes. The tests proved definitely that briquetting from soft coal slack was well justified. Unfortunately, all the briquettes tested were made with a pitch binder and were very smoky. They were probably not to be compared with the product of modern plants, such as Berwind at Superior, Wis.

An interesting phase of the soft coal briquette lies in the fact that from the dealers' standpoint they are most profitable to handle, as degradation is reduced to a minimum and waste almost

entirely eliminated. Pocahontas coal, for instance, slacks very badly in handling and shipping, but Pocahontas briquettes give very little degradation.

The power plant most adaptable to utilization of briquettes is the railroad locomotive. For reasons of design it is generally preferable to use large size fuel in locomotives rather than small, and there has, therefore, been more investigation and experiment on briquettes for this kind of power service than for the stationary practice.

From 1905 to 1907 one hundred tests were conducted by the Department of the Interior to determine the comparative value of briquettes and raw coal for locomotive use. Seventy tests were made on the Burlington, Rock Island, Missouri Pacific and Chicago and Eastern Illinois Railways, and twenty at the Altoona laboratory of the Pennsylvania Railroad, under the direction of the late C. T. Malcolmson. The briquettes were made at the Fuel Testing Plant at St. Louis (see Chapter XI). The St. Louis plant did not produce uniformly satisfactory briquettes. The Johnson revolver press was designed for European requirements and the roll press was still an experiment and made a product of varying quality. During the fall of 1905 locomotives of the Missouri Pacific Railroad between St. Louis and Sedalia, tested the burning quality of the briquettes. These briquettes were made on a revolver press from Arkansas semi-anthracite fines. Illinois lump coal, regularly used on that division, was used in comparative tests. The results showed an increased evaporation of 23 per cent and a decreased fuel consumption of 37 per cent per 1,000 ton miles in favor of the briquettes. The briquettes, before firing, were broken in halves, causing a large waste.

The New York Central lines, about the same time, burned briquettes also made on the revolver press at St. Louis. These briquettes were made of coke braize and were tested in freight and switching service. The report made by Mr. H. F. Ball, Superintendent of Motive Power, indicates that the briquettes, by reason of high ash and difficulty of ignition, as well as their large size were not satisfactory for the heavy service, but had advantages in switching service. The Missouri Pacific Railroad

tested briquettes of gas house coke and Illinois screenings, which gave better results. However, there was always an interval after firing when the steam pressure fell.

In June, 1906, the Rock Island Railroad tested 100 tons of Hartshorne, I. T., briquetted slack. Mr. C. A. Seley reported an average in the coal consumption of 26.2 per cent in favor of briquettes over Illinois lump. The ashes from the briquettes did not clinker. The briquetted fuel burned with an intense heat, and the depth of the fire was easily regulated. The briquette fire smoked only in firing. The next samples were shipped to St. Louis from the Rock Island, Missouri Pacific, Burlington and Chicago and Eastern Illinois Railroads, and briquetted on the Johnson and Renfrow presses, with 6 to 9 per cent of water gas pitch binder. The briquettes were tested by the railroad representatives. The water was measured. Flue gas analyses and front end and furnace temperatures were taken during the run. Samples of fuel, ash and cinders were analyzed. Steam pressure, feed water temperature, leakage, smoke, condition and thickness of fuel bed, method of firing and draft were recorded. The same engine, and, practically the same crew were furnished by the railroad for all tests on that road.

The record of tests, as collated by C. T. Malcolmson and published by Roberts and Schaefer (Briquetted Coal—Chicago—1908) is as follows:

In *Bulletin* No. 363 of the United States Geological Survey, W. F. M. Goss reports on an elaborate series of tests involving comparison of natural soft coals and of briquettes made therefrom—the tests having been carried out at the testing plant of the Pennsylvania Railroad Company at Altoona, Pa. The coal selected was what is known as Lloydell. The conclusions of this test were as follows, very largely confirming the results of the tests already noted:

The evaporation per pound of fuel is greater for the briquetted Lloydell coal than for the same coal in its natural state. This advantage is maintained at all rates of evaporation.

The capacity of the boiler is considerably increased by the use of briquetted coal.

The density of the smoke with th- briquetted coal is much less than with the natural coal.

TABLE XVI. LOCOMOTIVE ROAD TESTS SHOWING COMPARATIVE VALUES OF BRIQUETTED AND RAW COAL.

Railroad	C., B. & Q. R. R.				C., R. I. & P. Ry.		Missouri Pacific Ry.			C. & E. I R. R.		C., B. & Q. R. R.	
Coal shipped for test	Carterville District, Ill.				Hartshorne, Oklahoma		Pittsburg, Kansas			Sullivan Co., Indiana		Bevier, Missouri	
	Briquettes		Coal		Briquettes	Coal	Briquettes		Coal	Briquettes	Mine Run	Briquettes	Coal
Fuel tested	Washed Ill. 28A	Unwashed Ill. 28B	3-inch lump	Mine run	Unwashed I. T. 2B	Lump I. T 2C.	Washed Kan. 2B	Unwashed Kan. 2C	Lump Kan. 7	Ind. 1B 5B 6B	Ind. 1B 5B	Mo 10	¾-inch Lump
Proximate analyses fuel as fired: Moisture	5.67	5.41	5.59	4.70	2.1	2.54	3.44	2.49	5.47	7.14	13.86	7.63	11.40
Volatile combustible	31 09	31.86	32.67	35.04	35 65	36.98	33.21	31 15	29.15	36 02	32 18	32.86	33.55
Fixed carbon	50 75	51.38	52.80	47.14	50.74	53.97	52.45	47.33	49.81	44.18	41.97	39.52	42.12
Ash	12.49	11 35	8.94	13.12	11 51	6.51	10.9	19 03	15.57	12 66	12.06	19.93	13.93
Sulphur	1.11	1.87			1.63	1 75	3.67	4.43	4 8	3.63	3 48	4.50	5 78
B. t. u. per pound fuel as fired	11,969	12,163			13,015	13681	13,033	11,713	11,422	11,711	10,553	10,429	10,556
Fuel consumed per square foot, G. S. per hour actual	73.7	73.2	80 9	85.7	44.3	55.2	75	78.2	92.1	48	53	71	63
Water evaporated per pound fuel: Apparent, Actual	7.25	6.95	7.56	6 86	7.60	7.07	7.32	7 4	5.94	6.01	5.60	5.86	5.85
Equivalent, Actual	8.66	8.36	8.99	8.15	9.00	8.34	8.84	8.89	7.13	7.25	6.77	7 00	6.81
Equivalent, Actual dry fuel	9 09	8 86	9.52	8.56	9 20	8.56	9 15	9.12	7.54	7 79	7 86	7.58	7.91
Equivalent evaporation per square foot, H. S., per hour	9.97	9.94	11.60	11.20	6.96	8.02	9.49	9.97	9 42	6.56	6.8	6.78	6.76
Boiler horsepower developed	792	780	912	873	522	599	813	854	809	469	485	604	604
Boiler efficiency	69.5	66.5			66.8	58.7	65.5	75.8	60.2	59.6	62.4	64 8	64.2

The percentage of binder in the briquette has little influence on smoke density. (Note: not true in the case of anthracites and smokeless coals).

The percentage of binder for the range tested appears to have little or no influence on the evaporative efficiency.

The expense of briquetting must be lower than the amount of money gained by increased efficiency. This condition is by no means always realized.

With careful firing, briquettes can be used at terminals with a considerable decrease in smoke.

The briquettes appear to withstand well exposure to the weather and suffer little deterioration from handling.

In *Bulletin* No. 34 of the Bureau of Mines by Walter T. Ray and Henry Kreisinger, a similar series of tests are reported made at the shop yards of the Seaboard Air Line Railway Company of Portsmouth, Virginia. These were in a stationary locomotive boiler. This series of tests seem to show that run-of-mine coal gave better evaporation results than briquettes at low rates of working; at medium rates, a little difference was shown and at high rates, the briquettes were vastly superior. Attention is called especially to the excellent performance, therefore, of briquettes on heavy grades, and attention is further called to the desirability of lengthening combustion chambers and using a larger number of boiler tubes of smaller diameters and lengths where briquettes are used. All the coal was Pocahontas from McDowell County, West Virginia.

Soon after the completion of the briquetting plant of the Canadian Pacific Railway at Bankhead, Mr. Rolland Zwoyer, who had assisted in the design and construction of the plant, assisted the railroad officials in a test run comparing briquettes with the fuel from which they were made for locomotive performance. The actual data of this run are not to hand, but it is authoritatively stated that on a grade, where it was generally customary to split the train and carry it over the grade by two locomotives on each section; two locomotives burning briquette fuel were able to carry the train over the grade without breaking it up or calling for additional help—a most excellent high rating performance.

About December, 1907, a test run was made on the Atlantic Coast Line Railroad, the briquettes having been made at the

Government Fuel Testing Plant at Norfolk, Va., 6 per cent water-gas pitch was used as a binder; the coal was run-of-mine New River. The results as reported in *Bulletin* No. 363 are as follows:

TABLE XVI

	Coal	Briquettes
Number of test trips	16	16
Total pounds consumed	172,700	161,980
Average pounds consumed per trip	10,794	10,124
Average tons consumed per trip	5.397	5.062
Total engine miles	1,984	1,984
Total car miles	10,912	12,896
Pounds consumed per car mile	15.8	12.5
Average cars per train	5.5	6.5

The run was considered very satisfactory.

At the same time the Chesapeake and Ohio Railway used briquettes (similarly made from New River coal) on passenger locomotives. Good results were obtained from the firing point of view, but in this case the results did not show improvement in evaporative efficiency.

The railroad most experienced in the use of briquettes as fuel is the Lackawanna Railroad, which for a considerable period of time burned on their locomotives all the briquettes made by the Scranton Briquette Company at Dickson City, Pennsylvania. The burning of briquettes of this railroad was abandoned after several seasons for the curious reason that the firemen complained that the pitch in the briquettes caused skin rash. This point is at least debatable; certainly, no such result has ever occurred where asphaltic oil has been used as the binder, and cases of such complaint, generally speaking, are unusual.

The tests, which resulted in the adoption of briquettes by this railroad to the capacity of the supplying plant, were reported by Mr. R. G. Kilpatrick, Superintendent of Motive Power and Equipment, under date of June 24th, 1907, as follows: "The briquettes are oval in shape in their longitudinal and transverse sections. The first ones tested were 3½ inches long, 2½ inches wide and 2 inches thick, and weighed 5¼ ounces each. A new machine has been installed and briquettes reduced in size, dimensions being 3 inches long, 2 inches wide and 1¾ inches thick, weight 3⅝ ounces. The smaller briquettes give the best results. The briquettes are tough, of smooth exterior surface (except at fins) and under ordinary handling do not break.

"The first test was conducted in freight service on a standard consolidated engine designed to burn bituminous coal with fire-box of the semi-wide type, equipped with shaking grates. Four return trips were made between Scranton and Elmira with large briquette fuel, and to obtain comparable data four return trips were made with bituminous fuel. The briquette fuel was of the larger size noted above. A chemical analysis of the two fuels tested is as follows:

	Briquettes	Bituminous
Ash	13.7	11.0
Moisture	1.3	.5
Volatile matter	7.5	21.06
Fixed carbon	77.5	67.44
B. t. u. per lb. of coal	13,690	14,282

The analysis shows the bituminous coal of very high calorific value. An average of twenty Pennsylvania samples gives an average of 12,985 B. t. u. The bituminous coal used on test is of 10 per cent greater calorific value than the average of coals noted, and 4.32 per cent more than briquette coal. The briquette coal (13,690 B. t. u.) has 5.4 per cent greater calorific value than the average of bituminous coals noted. These comparisons are made so that results to follow can be judged on an equitable basis.

TABLE XVIII.

	Briquettes	Bituminous
Coal consumed per trip, lbs.	24,233	19,175
Water used per trip, lbs.	144,435	145,625
Average boiler steam pressure	194.1	190.1
Equiv. evaporation from and at 212°	6.87	9.12
Ashes, per cent	3.6	6.08
Coal consumed per 1,000 ton miles, lbs.	106.4	99.89
Lbs. per sq. ft. grate area per hour	69.22	57.89
Av. speed for actual running time, M. P. H.	18.05	17.68
Average actual running time	6 h. 59 m.	6 h. 41 m.
Average time on road per trip	10 h. 41 m.	10 h. 52 m.

It was found that when using briquette fuel the exhaust nozzle had to be increased in diameter three-eighth inch. This resulted in an increase of average M. E. P. of about 4 per cent. It was noted also on this test that the use of tools was eliminated with briquette fuel and use of shaking grates was limited to operation on each descending grate. Considering that firemen had no previous experience with this fuel and the benefits derived from increased nozzle diameters, this test was considered as favorable to use of briquette fuel.

"Subsequent tests were made with both large and small size briquette coal compared with anthracite pea coal on a 10-wheel, wide firebox, passenger engine between Scranton and Hoboken. The following is a summary of results obtained:

TABLE XIX.

Kind of fuel	Lbs. of coal	Lbs. of water	Average steam pressure	Evaporation	Nozzle Diam.	No. of cars
Small briquettes	29,400	204,540	189	8.24	3 13-16	7
Large briquettes	32,056	202,970	182	7.58	3 7-8	7
Pea coal	30,360	167,450	190	6.75	3 5-8	7

The increased efficiency of smaller size briquette fuel should be noted. A number of other tests were made, but those cited are representative of results obtained.

"In November, 1906, briquette coal was put into extensive use on narrow fire-box type of switch and pusher engines at various points on the road. The average consumption being about 200 tons per day, or a total of 20,000 tons to date. This fuel has proven satisfactory for locomotive service due to its free steaming qualities and reduction of labor in manipulation of the fire.

"That these anthracite briquettes have proven a satisfactory stationary boiler and locomotive fuel has been thoroughly demonstrated, and the improvements now being made at the plant will enhance its value. Signed R. G. Kilpatrick."

The National Railways of Mexico reported that the Crown patent fuel, bought in England, weighing 25 pounds each, burned exclusively on locomotives, showed an execution of 14 per cent greater than West Virginia Fairmount coal. The briquettes, as in South American practice, were broken up for firing.

In August, 1916, the Lehigh and New England Railroad made a comparative test with briquettes from the Lansford plant, soon after the Dutch process had been installed. Some difficulty was experienced on account of the firemen fearing the skin troubles which they had heard had occurred on the D. L. & W. R. R. These briquettes with asphaltic binder certainly caused no such trouble, as the firemen themselves readily admitted. The following were representative tests:

Test 1.—August 17th, Engine 18. Run: Pen Argyl to Martins Creek. Mileage 92 miles. Tonnage 2,300 tons. Length of run, 15 hours. Fuel: Soft Coal—better than average. Consumption: 10,500 pounds or 114 pounds per mile, or 0.0495 pounds per ton, per mile.

Test 2.—August 18th, Engine 18. Run: Pen Argyl to Martins Creek. Mileage 80 miles. Tonnage 1,720 tons. Length of run, 13 hours. Fuel: Briquettes, standard grade. Consumption: 14,100 pounds or 176 pounds per mile, or 0.104 pounds per ton per mile.

Test 5.—August 24th, Engine 19 (brick arch). Run: Pen Argyl to Hainesburg Junction: Mileage 60 miles. Tonnage 1,800 tons. Length of run, 10 hours. Fuel: Briquettes. Consumption: 12,000 pounds or 200 pounds per mile or 0.111 pounds per ton per mile.

It will be noted that on an engine designed for soft coal a considerably larger amount of anthracite briquettes were burned, which is not surprising considering the difference between the two fuels. However, at the location in question the briquettes were so much cheaper than the soft coal that an economy in dollars and cents was shown on this performance. Concerning these tests, Mr. W. P. Frey, fuel engineer of the Lehigh Coal and Navigation Company, who was on the engine, reports as follows: "The results are not exact, at all, as I could run no evaporation tests. Test 2: The Martins Creek run consumes an average of 6 tons of soft coal. Test 5: We used 6 tons of briquettes on a 5 ton run which makes 6:5 = 1.2. Our test results move between 1.4 and 1.2 1.2 was probably due to reduced draft as a consequence of the brick arch and more complete combustion. The heating value of soft coal tested was 13,400 B. t. u., the heating value of boulet 12,400 B. t. u., per pound of fuel. 13,400:12,400 = 1.08. This shows that at equal combustion efficiency you should only consume 1.08 times more briquettes than soft coal. We had no troubles with clinkers or blocked flues. We had, however, uneven burningout of the fire, due probably to uneven draft in the firebox. The briquettes have acted as a handy, clean fuel."

There has been a considerable interest in briquettes as a fuel for marine boilers, especially in the navy. Latterly, the universal adoption of oil burning for such purposes and the steady decrease in construction of coal-fired vessels would seem to argue

that there is little future promise in this field. None the less it is interesting to note that in 1907 the Battleship Connecticut made a test on briquettes in a trip between New York and Hampton Roads. It was noted that when the Connecticut passed out of the latter harbor with the fleet that it was the only vessel not producing heavy smoke. Tests on government tugs gave the same result.

In connection with the other tests made through the U. S. G. S., a series was run on the torpedo boat Biddle, also about 1907. The coal was West Virginia New River briquetted with 6 per cent water-gas pitch. The boiler was of the Normand type. For such a boiler but little increase in efficiency was shown, nor that steam could be raised more quickly. In general, briquettes were not recommended for torpedo boat practice as the result of these tests.

In all the government tests due allowance should be made because of the use of water-gas pitch as a binder, and that in rather small quantity. This binder has the sole redeeming quality of cheapness, but on the other hand its adhesion is poor, its burning quality low, and its nuisance capacity enormous—both in the stand-point of smoke and odor. That such excellent results were obtained where a binder of this nature was used speaks very well for the briquetting operation per se.

BINDERS AND PROCESSES

The binders commonly used in coal briquetting are:

Coal tar.

Coal tar pitch.

Oil.

Oil pitch, asphaltum, petroleum residuum.

Starch, flour and similar glutens.

Molasses—other pectin compounds.

Sulphite liquor—from paper mills.

No others are in use on a commercial scale.

The processes used to minimize the amount of binder and render it efficient, are:

1. Crushing and screening coal.
2. Melting or cracking binder.
3. Drying coal.
4. Proportioning coal and binder.

5. Mixing coal and binder.
6. Kneading the coal binder mixture.
7. Masticating the coal binder mixture.
8. Pressing into briquettes.
9. Baking or carbonizing the briquettes.
10. Cooling the briquettes.

CRUSHING AND SCREENING FINES

Ordinarily, the briquetting plant receives its material in finely divided condition. Where the product of coal breakers and washeries are turned over to the briquetting operation, the chances are that the material is received properly sized and can go direct to the dryers. Such is the usual practice where anthracite screenings and soft coal slack, from sizing operations, are used. Where old dumps are worked over, or the miscellaneous screenings of city yards are turned over to be briquetted, the screening out of oversize becomes necessary at *some point* during the operation. This oversize is available as boiler fuel, for market, or for crushing to size to join the other briquetting coal which has passed through the screen. Usually, it pays to burn or sell the oversize and not to crush it. Where extremely friable coals and lignites are mined, and it pays to put the entire product of the mine through the briquette plant, the first operation is screening over grizzlies, with crushing and grinding of over-size.

When crushing is employed in briquette plants, the hammer-mill type is adequate. Sometimes rolls are employed—toothed where coarse material is fed—smooth where the delivery of fine sizes is expected. The edge-mill type of grinder has also been used with success. Mr. G. J. Mashek has designed a special pulverizer for this class of work, wherein the crushing is done by percussion. This mill consists of a shaft upon which hammers are mounted. The coal, fed to the machine, is hurled by the revolving hammers against a succession of stationary crushing blocks located at the top; where it is broken by impact. The shattered coal, descending with the hammers to the bottom of the device, meets the screen through which it passes, broken down to 8 to 12-mesh, an excellent size for briquetting.

Ordinarily, a miscellaneous mixture of fuel sizes, arriving at the briquetting plant, would pass through a screen—revolving

trommell—first, the over-size being disposed of in one of the ways suggested in the preceding paragraph. The use of both screen and crusher should be avoided if possible. The use of the screen upon coal arriving at the plant means wet screening—always accompanied by clogging and trouble—especially obnoxious in the depth of winter when frozen masses of coal have to be handled. Only where the percentage of over-size is high, should preliminary screening be used.

It cannot be denied, on the other hand, that the efficiency and fuel economy of the drying operation is much improved by screen sizing, and removal of over-size before removal of moisture. Especially does the centrifugal de-waterer work at a disadvantage with miscellaneous sizes in mixture. Each case must be determined on its merits. A great excess of large size material, a percentage of sticks and stones, especially if accompanied by enough moisture to justify the centrifugal de-watering machines—would argue for rotary screens as the first operation.

CRACKING OR MELTING BINDERS.

There are two schools in coal briquetting—which may be designated in accordance with the binder used the Pitch School and the Tar School. By pitch, as previously explained, is meant material that requires crushing, or "cracking," before being mixed with the briquetting coal, and, when mixed, is in a powdered form. The simplest method of mixing pitch in this manner, is to pass the ground pitch into the coal crusher with the coal. In this case the pitch has to be carefully measured, and the coal as well, before passing into the mill. This pitch process—also called the hard pitch process—is a favorite in England. The Yeadon Company have devised a special proportioner for delivering the pitch in proper quantity to a measured quantity of coal, and, indeed, all the English companies have well-defined methods for making such admixture. In Germany, the Fohr-Kleinschmidt method has recently come into vogue. In this process the pitch after being pulverized and proportioned,—usually by means of proportioning tables (hereinafter described)—is thrown into the horizontal paddle mixer in very finely divided form—practically atomized. In all cases the grinding together of the pitch and coal in the mill is followed by a paddle mixer in which superheated

steam is used, and sometimes by a fluxer as described later. In general, the hard pitch process is far better adapted to piston and mold presses (especially the revolver type) while the liquid binders are clearly preferable where rotary presses are used. In the latter case—at least with the larger plants—the binder is delivered in tank cars. Where melting is required in order that the binder be pumped from the cars, such cars are equipped with

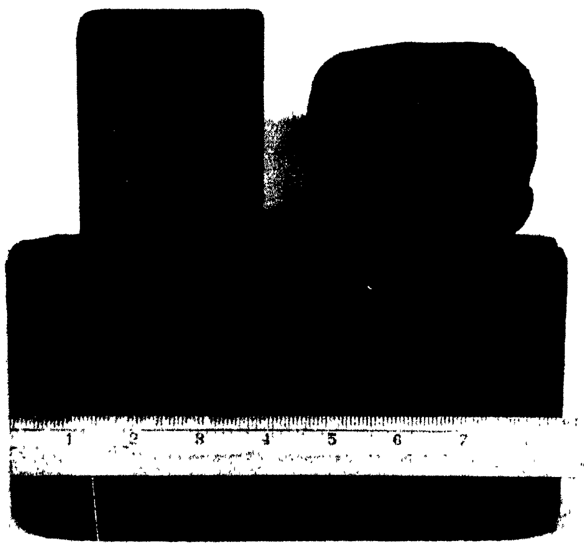

Fig. 106.—Briquettes made on the Couffinhal Press. Fohr-Kleinschmidt Process.

steam coils and, on arrival at the plant, the coils are hooked to a steam line, the binder melted and pumped to the storage tanks. In smaller plants the binder arrives in packages (barrel shape) which are broken up, the binder cut by axes and the pieces melted in the main binder tank. Water-soluble binders delivered in tank cars or barrels are, of course, sufficiently liquid to flow without heat treatment.

The binder handling equipment at the plant of the Lehigh Coal and Navigation Company is especially noteworthy on account

of its extreme flexibility. The valve arrangement is such that the car contents can be delivered to any one of four tanks and the contents of any of those tanks can be delivered to any one of the mixing units in the plant.

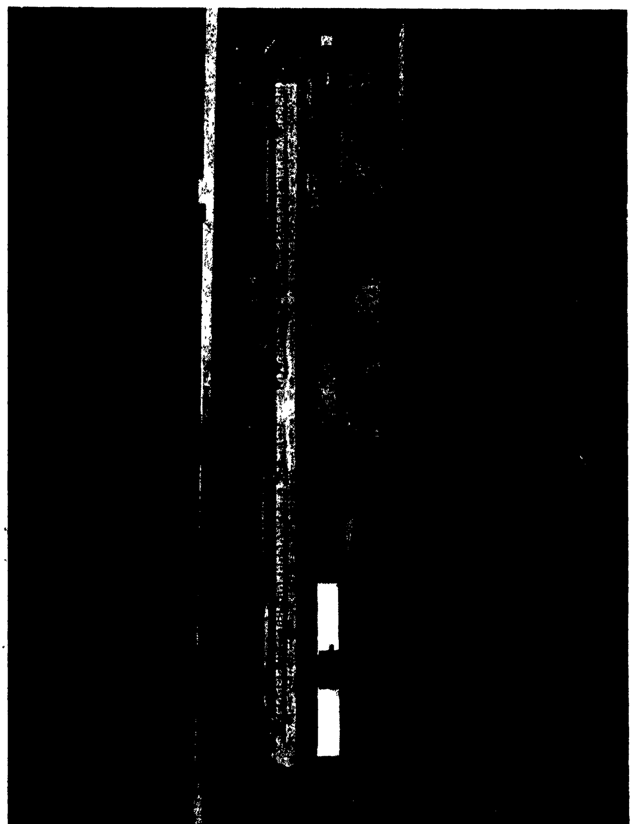

Fig. 107.—The Zwoyer Calibrated Binder Feed.

Binder tanks contain steam coils for the same reason as do tank cars: Steam is kept up at all times where asphaltic or heavy tar binders are used. The congealing of the binder from lack of steam sometimes causes long periods of interrupted produc-

tion and it is often cheaper to keep up steam during a shut-down of the plant rather than to permit such congealing. Binder tanks are usually cylindrical and placed horizontally. Whatever the binder, it is wise to insert filter screens to intercept dirt or scrap pieces, which may—if not removed—clog the lines. From the tank the binder is pumped—usually by a Kinney type of oil pump —to the head of the mixer. At the end of a line a valve is set to insure the delivery of the binder in proper quantity. Where steam coils are used in the tank, a steam pipe must be provided to accompany the binder pipe, and it is preferable that one of these pipes be within the other.

A novel adjustment for the binder feed has been designed by Mr. E. B. A. Zwoyer (Figure 107). A pointer is set on a scale adjusted to run by clockwork parallel to the decreasing surface of the oil in the binder tank. The speed of the descending pointer is set at the rate at which the proper binder proportion is to be fed. A salt-water column is placed parallel to the pointer showing the actual level of the binder in the tank. As long as the salt-water column and the pointer descend at equal speeds and maintain their relation unchanged, it is known that the proper binder percentage is being carried to the mixer. If the oil is fed too rapidly or if the pipe is clogged, a disparity between the two rates of speeds occurs immediately. An electro-magnet is set so as to close a circuit the instant this condition occurs, and an alarm is automatically rung, so that a correction can be made immediately. This is of extreme importance, for a variation in the binder percentage either way is fatal to the quality of the final product. Too much binder, aside from being wasteful, gives a soggy and smoky briquette; too little binder gives a briquette incapable of shipment without disintegration. In addition to the regulation of binder feed, this apparatus carries a traveling-time sheet, which records automatically the hours of press operation.

DRYING.

Most materials—and especially coal available for briquetting —come to the plant in various degrees of saturation. It is always of benefit to dry the material before proceeding to the mixing and pressing operations. The following reasons are given to explain the universal use of dryers— and especially heat dryers— in the briquetting of coal and other materials:

(1): Wet material is very difficult to feed; it runs unevenly and in lumps, and thereby creates difficulties in proper proportioning of binder and pulverulent material.

(2): In cold weather wet coal freezes into lumps, and the disabilities outlined in the preceding paragraph are much emphasized.

(3): A merchantable briquette should contain as little moisture as possible. The presence of excess moisture seriously impairs the heating value.

(4): In practically all cases, it is of advantage to feed material to the mixing equipment hot as well as dry. Provided the temperature is within proper limits, a better distribution of binder is effected. In the case of water-soluble binders, a certain amount of excess moisture in the binder is evaporated by the sensible heat of the dried coal. In the case of the oil and pitch binders, it is practically impossible to make a proper mix with cold coal. The hot melted binder coming in contact with cold, wet coal solidifies, and thereafter proper mixing is out of the question unless some form of re-heating—as, for instance, a malaxeur—is used; and this machine, too, cannot in such circumstances realize its full value.

For the above reasons, it is usual to find in all fuel briquetting plants (with the exception of those using carbonized products direct from the retorts or ovens), drying equipment, embodying heat in some part at least of the operation. While with very wet coals—that is above 10 per cent moisture—(and the fact applies to other materials)—it is of advantage to employ mechanical de-watering prior to the heat treatment, it is none the less true that the centrifugal de-waterer has not been very largely employed in connection with fuel briquetting as yet. However, the work of these de-waterers in connection with coal washeries has been so successful and so important that it is probably but a matter of a short time before they will be adopted generally in the briquetting business. They cannot supplant the heat dryer, for the best cannot reduce the moisture low enough for equable feeding, and, of course, the heat element is missing. On the other hand, they are capable of driving out the excess moisture at a cost many hundred per cent below that of the rotary dryers. So far, the only installation in connection with briquetting was that of an Elmore

centrifugal dryer at the plant of the Lehigh Coal and Navigation Company, which has been installed since the description of that plant was published and has not been a success in operation.

A typical successful centrifugal dryer is the Wendell. At the coke plant of the Colorado Fuel and Iron Co. are installed and in operation five of these machines, three of which are of large size. They have a drying capacity of 2,400 tons of coal per day to an average moisture content of 7 per cent. Figure 108 shows a cross-section of this machine. The coal is received in a hopper (1) and then passes into two distributing chutes (3), which are

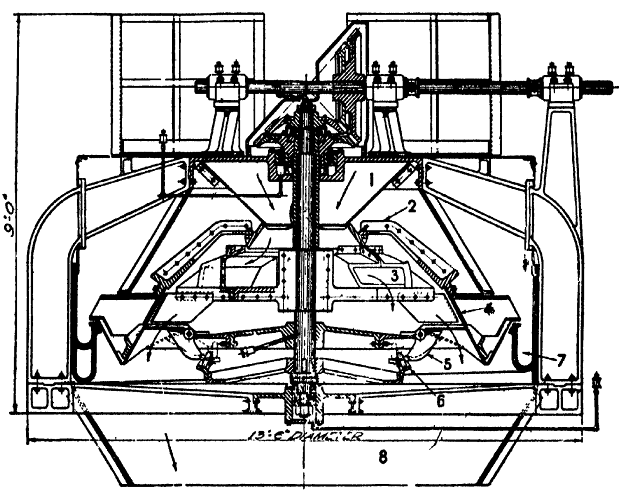

Fig. 108.—Cross Section of Wendell Centrifugal Dryer.

set diametrically opposite each other. These chutes throw the coal against a conical screen (4) and over a gate (5) whose operation is controlled by means of a cam (6). The chutes and the cam are carried on a shaft rotating at a higher speed than the centrifuge (2). After a suitable period of whirling, the coal drops into the hopper (8) through the gates (5). The water passes through the screen to the sluice (7).

Of the dryers employing heat, the following have been found adaptable to various kinds of briquetting:

(1) Steam dryers.
  Table.
  Tubular.
(2) Furnace gas dryers.
  Direct-heat.
  Semi-direct.
  Indirect.

The steam table type of dryers have been fully described in Chapter IX. There have been no installations in this country—at least as applied to the coal briquette industry. Abroad, the steam table dryers applied to coal briquetting are made by the Tigler Company at Duisburg and by the Zeitz Foundry and Machine Company of Zeitz. Several of the coal briquetting factories in Saxony and Silesia have adopted this type of dryer in addition to those used in the brown-coal industry.

The rotating-drum steam dryer has also been described in Chapter IX. It is generally spoken of as the Schultz type. In this country G. J. Mashek manufactures such a dryer in connection with coal briquetting, modified in accordance with his own design, to be used where coal contains less than 10 per cent of moisture and is pulverized to a size suitable for briquetting before being fed to the dryer.

Ruggles-Coles and other dryer manufacturers also make steam-rotating drum dryers adapted to the drying of coal, if so specified, but more especially to the drying of organic fine materials like cotton seed, grains and the like. Outside of the attempts to briquette lignite—where steam drying has definitely been proven to be essential—there has been but little installation of steam dryers—at least so far as the briquetting of fuel or ores is concerned.

Direct Heat.—In practically all the important fuel briquetting installations in this country, some form of furnace gas drying has been employed and of these it is probable that one or the other of the direct-heat methods has been used in the majority of cases. There have been two radically different methods of employing such direct heat. The first consists of a simple rotating cylinder provided with flights for lifting and spreading

the material across the interior through which the hot gases pass. The gases are driven by blower or induced (together with the evaporated moisture) by fan or stack, or blower and exhaust are combined. In designing such a dryer, care must be taken that the diameter and length are such that the necessary volume of gas can be passed through at a velocity slow enough to allow for complete evaporation, without causing excessive dust losses. There has been great variation in the designs of this type of dryer in the character of the flights for lifting and spreading the material.

It has sometimes been the practice to introduce the furnace gases directly against the cold and wet material. However, many authorities prefer the arrangement of the gases running in the opposite direction, lest the hot gases striking the wet material be quenched and the efficiency of the drying apparatus badly impaired. It must be said, too, that such a dryer is not economical in operation. The temperature of exhaust gas is generally high and a radiation loss is considerable. The furnace combustion is frequently incomplete and there is a loss of efficiency due to smoke formation.

In some cases single-shell dryers have been enclosed in brick and radiation loss thereby greatly reduced. Further, when hot products are permitted to pass between the brick wall and the exterior of the shell, the tendency of the drying material to stick to the walls of the cylinder is corrected. Dryers of this class, made by the Vulcan Iron Works, have given satisfactory performance at the Lehigh Coal and Navigation Company plant. The furnace is usually of the Dutch oven type, furnished with blowers and sometimes with exhaust. The installation cost is small and, for this reason, they have been very widely used and recommended.

G. J. Mashek says in respect to the direct-heat rotary dryer —(and he has incorporated several of his own design in plants constructed by him) as follows: "These dryers are invariably used for either preliminary or final drying of very wet coal preparatory for briquetting."

A second method of applying direct heat for drying purposes to wet fine materials is that adopted by E. B. A. Zwoyer as a preliminary to the introduction of the binder and the mixing.

This design is in effect a paddle mixer or pug mill with a furnace and flue attached, and the hot gases pass through a trough, containing rotating paddles, stirring up the coal. The apparatus consists of a horizontally arranged chamber, lined with fire brick and having a curved trough-like bottom. The material is delivered to the receiving end of the chamber through a pipe in the top and is discharged from the other end through an opening in the bottom. The top wall is made of angle iron supporting fire bricks. Running longitudinally through the chamber is a shaft mounted on bearings outside and driven by a belt and pulley at a fairly high speed. The shaft carries a number of cast iron paddles projecting from hubs which fit over the shaft. The shaft is usually square. These paddles have their front faces beveled at a slight angle, so as to produce a forward but not too rapid feed of the coal toward the discharge end. The ends of the paddles have lips projecting from their front faces, which serve to scoop up the mix from the curved bottom and throw it, well separated, against the top of the chamber. Thus the upper part of the chamber is kept filled with the suspended pulverulent material. At the discharge end of the shaft are paddles whose faces are in a plane parallel with the shaft. These serve to discharge the material. The coal is fed from a feed hopper by a roller feed. Hot gases produced by the combustion of fuel in a furnace pass into the chamber at its discharging end and travel in a direction opposite to that of the coal and pass out through the up-take.

One or more of such trough mixers are used in preparing the coal prior to pressing and at a suitable point—usually the second or third of a series of six of the above described apparatus—the melted binder in measured quantity is sprayed into the coal. For example: in a series of six of such machines the first one or two would be classed as dryers and the last four or five would be mixers or combination dryers and mixers. The combination is an extremely compact and workable mechanism. It has been installed with success at the Canadian Pacific briquetting plant at Bankhead, Alberta, and at the Stott Briquette Company's plant at Superior, Wis.

Semi-direct Heat.—What is known as the semi-direct heat dryer consists of a rotating cylinder with a centrally located heat flue

attached to the cylinder longitudinally and rotating with it. A typical example is the Ruggles-Coles Class "A" (see Figure 109).

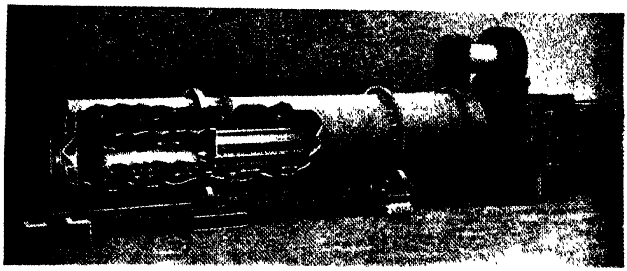

Fig. 109.—Semi-direct Rotating Drum Dryer. "Ruggles-Coles Type."

Two long concentric steel plate cylinders form the shell, and are set with the delivery end slightly lower than the head. The inner cylinder acts as flue for the hot furnace gases. The outer shell circumscribes the space wherein is placed the material being dried. These cylinders are rigidly connected midway between the ends by heavy braces. The principle of carrying the hot gases through the central flues avoids radiation loss and obviates the necessity for exterior brick work except that required for the furnace. Such a dryer is far more economical in operation than is the direct-heat drum. A recent improvement calls for a rectangular center flue giving greater heat surface for the same sectional area. Shelves are fastened to the interior of the outer shell, running parallel to the axis of the dryer for its entire length. As the drum turns, these plates lift and drop the material being dried on the hot inner shell, and by the inclination of the drum, the material is led from the feed to the delivery. At the discharge head are buckets which discharge the dried material through a central delivery casting. The inner cylinder terminates at a point some distance from the discharge end of the dryer, and, consequently, the gases are discharged directly into the space occupied by the drying material. They are inducted through this space by means of a fan to the feed end, and are discharged to the atmosphere at that point. This type of dryer has been installed at practically all the installations of the Malcolmson Briquette Engineering Co., where dryers are required; notably, at the Berwind Fuel Company plant at Superior and the Pacific Coast Fuel Company at Seattle.

The Indirect Heat form of dryer is one in which the gases are kept from any direct contact whatever with the material to be dried. Such dryers have not been considered as efficient for the drying of materials to be briquetted, especially fuels. Ordinarily, such a dryer would consist of the same rotating shells, one within the other, as described in the case of the semi-direct dryer, with the exception that the inner shell is carried through to a stack at the discharge end, thereby preventing any contact with the drying material.

In calculating for drying equipment provision must be made to use a certain number of thermal heat units; first, to raise the temperature of the material to 212°; second, to raise the temperature of the water contained to 212°; and third, to evaporate that required part of the water. Knowing the specific heat of the material, the initial and final percentages of moisture and the initial temperature, the theoretical fuel requirement may be calculated. Then the heating value of the fuel and the thermal efficiency of the apparatus must be ascertained whereby the quantity of fuel required for any capacity may be exactly determined. Seventy-five to eighty-five per cent is good thermal efficiency for a coal dryer.

PROPORTIONING AND MIXING.

We now have the coal or other fine material dried and ready to be mixed with the binder, and the binder melted, if liquid, and pulverized, if solid, ready to be mixed with the coal.

A problem arises in securing the proper proportion of coal and binder. The quantity of binder to be added to a given quantity of coal is, for best results, to be limited each way, and the limits are narrow. Too little binder means large loss by abrasion and breakage, very unsatisfactory performance in the fire; while, on the other hand, too large an admixture of binding material will—in the case of inorganic binders—result in difficulty in burning and too high an ash addition; and, in the case of all organic binders, too high an additional expense; and, especially in the case of the oil and pitch additions, in smoky combustion and poor resistance to summer and tropic conditions of transportation and storage. Many elements have to be considered in deciding just how much binder should be added:

1. *The Density of the Material.*—Other conditions being equal it is obvious that heavy material will require far less binder per ton than light material. The limits are wide; a binder which will make a satisfactory briquette of iron ore with 4 per cent admixture would probably be required to the amount of 30 per cent in the manufacture of charcoal briquettes.

2. *The Porosity of the Material.*—Porous material of high fissility requires an extra quantity of binder to fill the pores. Such quantity is really a waste so far as actual binding alone is concerned, and frequently is a very serious item.

3. *Character of Surface.*—Rough, fragmental material requires a far thinner film of binder between the grains than does rounded, well-polished material. As an instance: if two different kinds of quartz sand were being briquetted—that from the desert and that from the sea—it would be found that the rough corners of the desert sand would permit its being briquetted with a far smaller addition of binder than in the case of the polished sea sands.

4. *Size of Grains.*—The quantity of binder needed varies inversely with the diameter of the grains as well as with the density of the fine material. In fact, the variation of the size of the grains is by far the most important factor of all in determining the quantity of binder admixture. Assuming the grains have radius r, the specific gravity d, and unit weight w, the amount of surface to be coated is $\frac{3w}{rd}$, obtained as follows:

Each grain may be assumed to have a spherical volume of $\frac{4}{3}\pi r^3$. The weight of each little sphere is, therefore, $\frac{4}{3}\pi r^3 d$. The number of grains in the given weight are equal to that weight divided by the weight of each, or $\frac{w}{\frac{4}{3}\pi r^3 d}$. The surface of each grain is $4\pi r^2$, and this value multiplied by the number of grains gives the formula above. (As calculated in *Bulletin 24 of the Bureau of Mines*).

The same publication gives the following tabulation showing the relative amount of surface to be coated by a binder for various diameters and the very rapid increase in surface to be coated with the decrease in radius of grain:

TABLE XV.

Number of meshes to inch	Relative amount of surface	Number of meshes to inch	Relative amount of surface
1	1	80	110
2	2	100	150
4	4	200	300
10	12.7		
20	25 4		
30	37.9		
40	50.8		
50	81.9		

It should be borne in mind that these figures apply to carefully sized coal in which the grains are all of equal diameter. In addition to coating the surface of these grains, we must figure as well upon filling the dead space between them with binder which of itself exercises no binding quality. The experiments of Richardson found that the percentage of void space in a barrel of shot is about 32. It has been shown by Dr. G. F. Becker ("Modern Asphalt Pavements," Clifford Richardson) and the U. S. Geological Survey that the amount of void space between grains of uniform size is independent of the size of the grains. It is very evident that too close sizing of coal, or other fine material, would result in a tremendous increase in binder admixture simply to fill voids. As a matter of fact, in practically all briquetting, these voids are filled to a great extent with smaller grains.

If we are briquetting a material of normally one-eighth inch grains—and this is an excellent size in fuel briquetting—a good division would be 60 per cent of one-eighth inch and 40 per cent of smaller sizes. One of the advantages of the Dutch process and of mastication, hereinafter mentioned, lies in the fact that it is, partially at least, a preliminary packing wherein the interstices between larger grains of coal are filled with smaller ones squeezed into position by the heavy rolls (and if not existent are made from larger pieces by the heavy rolling action). Although in passing from the conveyor to the press, this association is largely broken up again, it is resumed with great ease when the material comes under the heavy pressure of the press rolls.

The character of the binder as well as its physical condition is an important factor in determining percentage of admixture. Different binders: oil, coal tar pitch, sulphite liquor and the like are required in different percentages, all other conditions being

equal. An excellent example of different proportions of various binders required to briquette the same material under the same conditions is shown in Table XXII on page 442 (Appendix), illustrating the experiments of the Canadian Lignite Utilization Board, in the binder research for the briquetting of carbonized lignite. A binder that has been dissolved or heated until it flows like water will coat the grains thoroughly and at minimum expense, and every effort in practice should be made, at some part of the operation, to bring the binder as closely as possible to such a condition either by solution or by heating. The more viscous the binder, the thicker the coating necessary on each film to secure the desired result; the thicker the coating, the higher the percentage required. With liquid binders the peak of liquidity occurs at the moment of contact with the fine material. Where solid binders in pulverized form are added, this condition is obtained later in fluxing or horizontal paddle mixing in a stream of superheated steam. The amount of binder added will depend upon the character of the after-treatment or treatment they obtain after leaving the press. Where briquettes are cooled by the sudden shock of a cold water plunge, more binder is necessary than in cases where the briquettes are given ample opportunity to cool in the air. Where soluble binders are used and carbonization and cooling are necessary a far larger admixture is needed to obtain a sufficiently carbonized coke bond than is the case where the briquettes can be marketed or used without such treatment. On the other hand, briquettes made with a lime binder would require less lime admixture if their formation is followed by a steam or carbon-dioxide treatment than if the bond of such is obtained simply by exposure to atmospheric air. The amount of binder that may exist in the coal either as bitumen or something else is important under some conditions. Bituminous coals, being less dense, require more hydro-carbonaceous binder than do anthracite coals, although a saving in binder sometimes occurs directly proportional to the percentage of the coal soluble in carbon-disulphide.

The coal and the binder in most installations come together at the head of a paddle mixer. In some cases, where a hard, pulverized binder is used, a preliminary mixing is done in a Williams mill followed by a horizontal paddle mixer or pug

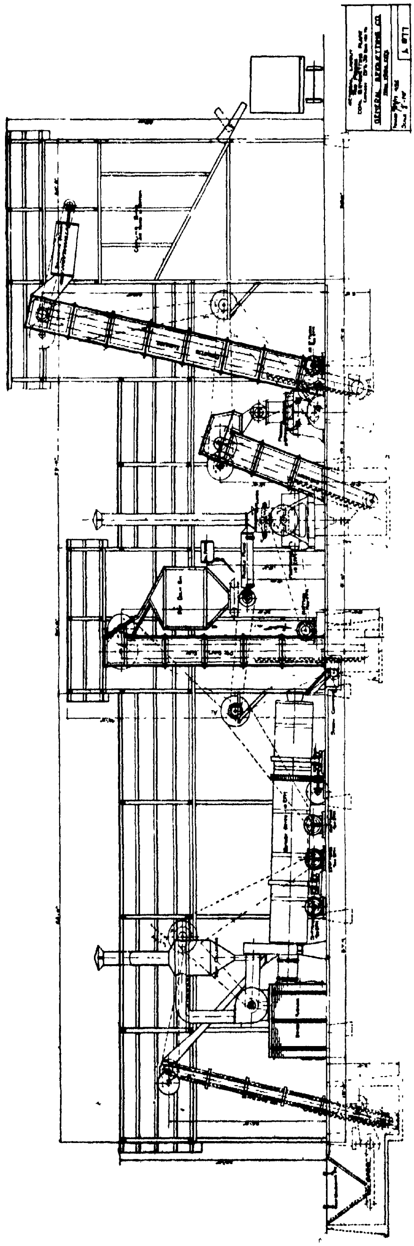

Fig. 110.—Layout of Typical Coal Briquetting Plant. (Dutch Process).

mill. In all cases careful proportioning is necessary. The coal discharged from the dryer should be screened at this point to take out oversize, if any, and tramp iron. The screened product goes to a hopper bin, which should be small, because large storage at this point would result in loss of sensible heat. Below this bin is a gate set to regulate the flow of coal to the apparatus. The coal may be removed from the gate by apron feed conveyor, as shown in the general layout of a coal briquetting plant (Figure 110) or by means of a revolving table as shown in Figure 111. In this installation the coal is discharged on the

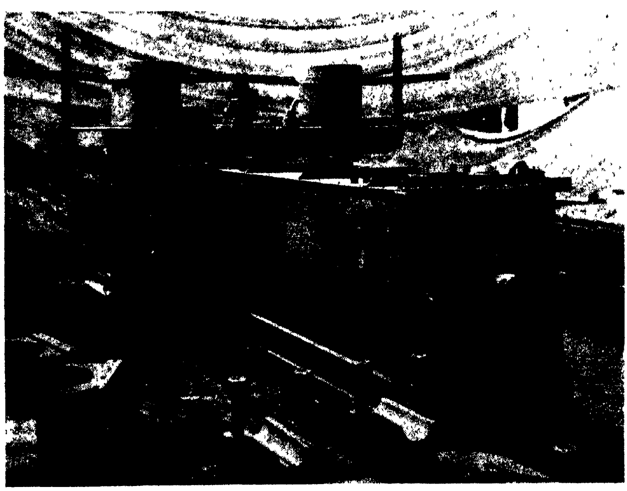

Fig. 111.—Mixing Tables and Paddle Mixer. American Clay Machinery Co.

table and is carried away from the gate opening by the table's revolution to a point where a stationary plow turns it into the paddle mixer. One or more of these tables is used where different coals are mixed, and a similar table and gate are employed in some installations to feed a measured amount of hard pulverized pitch where that class of binder is used.

Another system of continuous discharge and feed from the proportioning gate occurs in Germany, and is called a rolling slide or supply shoe. Below each gate an iron roller, running on inclined rails, is pushed backwards and forwards by a connect-

ing rod and crank, As the shoe travels forward, it carries with it the coal, which has fallen from above and is dropped on the return motion. Such an installation has never been made in coal briquetting plants in the United States; either the apron conveyor or the feed table has always been used to convey the dried material from the measuring gates to the mixer head.

We now have the coal supplied in a steady stream meeting the binder—if not already met—and whatever the method or binder used, it is practically universal practice to use a horizontal trough paddle mixer at this point (Figure 111). Such a mixer consists essentially of a trough—about 12 feet long is the maximum

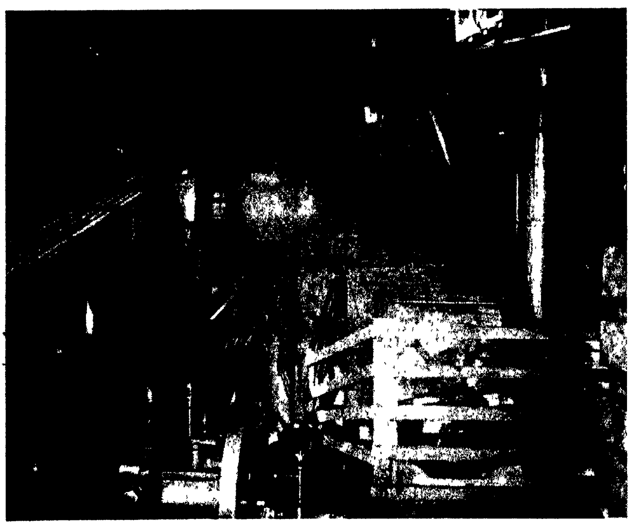

Fig. 112.—The Zwoyer System of Drying Coal and Mixing with Binder. Nest of Dryer-mixers (within brickwork) at the Briquetting Plant of the Canadian Pacific R. R., Bankhead, Alberta, Canada.

—in which a horizontal shaft is longitudinally placed on which are paddles so arranged with lips as to force the coal binder mix —which for convenience we shall hereafter call a "flux"—down its entire length, discharging it with the particles of fine material fairly well coated with binder. Such a machine is in effect very similar to the Zwoyer dryer, already described, except that the trough is of metal and does not require brick lining. In some

plants there are 50 feet and more of such mixers; in others a single mixer suffices because of the use of masticators or vertical fluxers or both. The horizontal mixers are fitted with steam jets in most cases. The injection of steam tempers the mix, helps the binder keep its fluidity, and thereby enhances the efficiency of the mixing—this irrespective of the character of binder used. Where pulverized hard pitch is used and the preliminary mixing is done in a Williams mill, it is customary to use superheated steam in the paddle mixer and there obtain the liquidity desired. It must be stated, however, that it has never been possible to reduce the amount of hard pitch employed to as low a percentage as is possible with melted liquid binder of the hard hydrocarbon class.

FLUXER OR MALAXEUR TREATMENT.

It cannot be emphasized too strongly that a thorough blending or "fluxing" or kneading, as it is sometimes called, of the coal and binder mix is necessary to obtain the coating of each particle with a thin film of binder. Such a result is in some cases achieved through the medium of simple paddle mixers, and in others, of the paddle mixers plus mastication. Many authorities abroad and in this country consider the addition of a vertical malaxeur an excellent medium for achieving this purpose either with or without mastication. The best practice calls for its insertion before mastication. Where mastication is not used—and especially abroad in connection with the Couffinhal and revolver type presses—the malaxeur is inserted directly above and feeding into the press hopper (see Figures 18 and 24, Chapter II). The simpler form common to the foreign pressing machines consists of a sheet iron cylinder resting on beams. Through the center of the cylinder passes a revolving shaft with radial shelves arranged for storing and kneading the coal binder mixture as it passes downwards through the mechanism, the drive being operated by a bevel gear below. The cylinder is fed through an opening in the top. It is closed at the bottom, but openings at the sides serve for a discharge of the fluxed mix to the masticator or the press. The discharge gate is adjustable, operated like the familiar ore bin gate. On the inside cylinder wall short jets are arranged spirally where outside connection is made with steam pipes and either superheated or high pressure steam impinges upon the mixture.

MASTICATION

The masticator is a feature of a patented process known colloquially as the "Dutch" Process; (U. S. Patent 1,114,715 issued to Adriaan van Hall, Fritz Basenau and Richard van Haagen). The process is important on account of its success at large plants; notably, the Lehigh Coal and Navigation Company, Lansford, Pa. and the Berwind Fuel Company, Superior, Wis. (see Chapter XI).

The process consists of mixing solid carbonaceous fuel and liquid hydro-carbonaceous binder in accordance with methods already outlined, and discharging the mix to the pan of a masti-

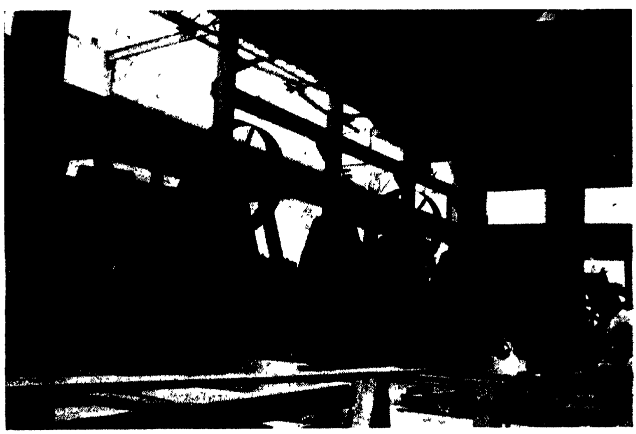

Fig. 113.—Three of the Four Masticators at the Briquetting Plant of the Lehigh Coal and Navigation Company, Lansford, Pa.

cator, which may be described as an edgerunner of a special type with stationary pan and revolving rollers. An adjustable scraper carried on a supporting arm follows each roll and continually ploughs up the material so that it is gradually forced to the center of the bed, where it is discharged through an opening and carried to the press. Before leaving the masticator it is ground on an average of six to eight times.

Masticators are built in two sizes—8 feet and 12 feet—this being the diameter of the base or table, and with drive either overhead or underneath. Figure 114 illustrates a sectional and plan view

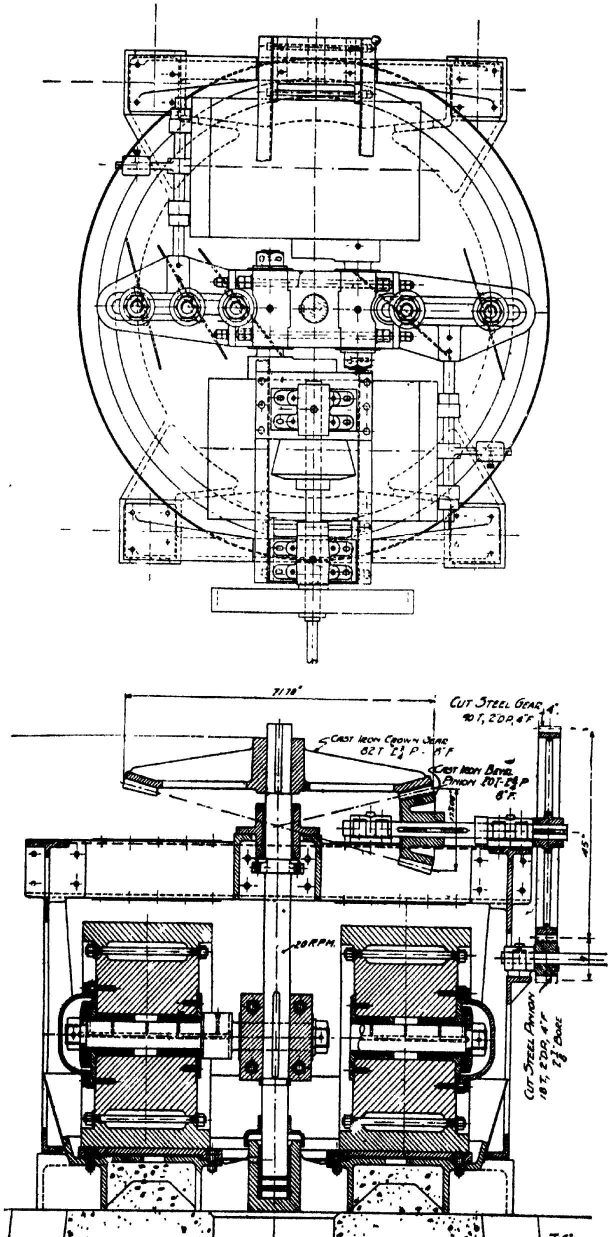

Fig. 114.—Plan and Elevation of Masticator.

of an 8-foot machine with overhead drive. The drive frame consists of two heavy A-shaped cast iron side frames rigidly bolted to the bed plate. These are connected at the top with a cross girder made up of two steel channels reinforced with steel plates. The vertical shaft, carrying the rolls and plows, is a hammered steel forging. Two cast iron arms which project across the table on opposite sides at right angles to the axis of rolls are bolted to the driving head. These arms carry the adjustable plows. The rolls on the 8-foot machine are 48 inches diameter and from 24 to 30 inches wide; on the 12-foot machine the rolls are 60 inches in diameter and 40 inches wide. The width and weight of rolls vary to suit the nature of the material treated. The body of the rolls is gray cast iron. The rims or tires are a hard white iron. The entire weight of the 8-foot machine is 25 tons; of the 12-foot machine, 48 tons.

The microphotographs of the interior structure of a briquette (magnified 20 diameters), shown in Figures 115 and 116, illustrate in a clear and definite manner the effect of mastication. These briquettes were both made from the same coal with petroleum

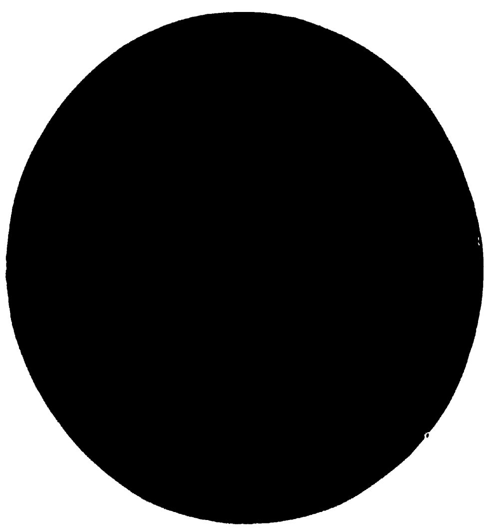

Fig. 115.—A Briquette Made from Soft Coal without Mastication. Note Spaces between Particles Filled with Binder.

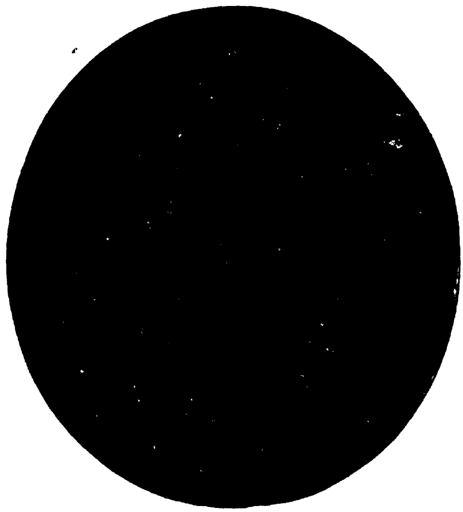

Fig. 116.—A Briquette Made from Soft Coal with Mastication. Note Homogeneity of Structure.

residuum binder. Figure 115 was made by ordinary mixing and is as good a briquette as can be made by such methods, but it is simply an agglomeration of particles glued together and considerable binder is wasted filling the numerous void spaces. Figure 116 has been made with a masticator, but with about 3 per cent less binder than the other. The structure of such briquettes is equal in strength and hardness to the original coal and, in some cases, exceeds it.

The underlying discovery of the process is that when the solid and liquid fuels above mentioned, and especially with a petroleum residuum used as binder, will when rolled for a certain time in this machine, form a relatively dry plastic substance as opposed to the wet and sometimes sticky mass coming from the mixers. At least such is the condition obtained when an oily binding medium is used. The reason is that a certain amount of absorption of the hydro-carbonaceous mass takes place imparting a cohesive quality to the solid fragments. Where water-soluble binders are used—and this applies not only to coal but to all classes of fine material subjected to briquetting—the effect is contrary. The

water is squeezed out from the mass and a mix that is apparently dry on entering the masticator comes out very apparently wet. If too much moisture be present, the mass may take a putty-like consistency which is then too wet for pressing. As a consequence, considerable care must be taken in masticating such mixes lest the percentage of binder added be too high; and it is very evident that in such cases the masticator is a very valuable element of binder economy. With the oil binders as well it brings about so efficient a distribution that a mix fit for the press is produced at an expenditure of 1 to 2 per cent less binder than is the mix where simple mixing is employed.

An application of the masticator to ore and flue dust briquetting has been covered by patent 1,334,331 issued to Felix A. Vogel. Mention has already been made of the value of the masticator in crowding the smaller sized particles of fine material into the interstices of the large particles, thereby relieving the press of a large part of this burden.

PRESSING.

In a briquetting plant a good press is of paramount importance. Various of the presses available for briquetting have been described in Chapter II. General considerations are as follows: The smaller the briquette, the lower the pressure per square inch necessary to achieve a good result. In all presses uniformity of feed is absolutely necessary. In the piston and mold presses this is a simple matter. In the rotary or Belgian presses complicated feed mechanisms were necessary until the original Zwoyer press was installed at the Bankhead plant in Alberta. Where piston and mold presses are used, considerable latitude as to moisture content is admissible, but a high liquid content would result in low pressure because the excess of moisture cannot escape from the molds and prevents the pressing together of the coal. Too great a moisture in the mix where rotary presses are used also results in low pressures and a product soggy and useless. On the other hand, material fed too dry to the press will, in the case of piston and mold work, develop laminations and cleavage planes—sources of weakness, and, in the case of tangential or

roll presses, the result is far too high a pressure, frequently resulting in the breaking of the briquette in halves immediately after its formation. Presses must be selected having in mind their adaptability to the mix fed to them, as well as to the market condition their product is called upon to meet. In general, fuel briquettes in North America are made upon some form of tangential or rotary press. In South America, large fuel briquettes are used, mostly made on the revolver presses of England, and imported from that country.

AFTER-TREATMENT OF BRIQUETTES.

Cooling.—The ideal method of cooling briquettes is to carry them slowly through the air until they are set and cool enough to go to the bin. In the case of lignite and sawdust, under the German open-mold systems the whole secret of success is that proper use of the cooling channel down which the briquettes are forced by the press piston through the open mold. Removing briquettes from this cooling channel before thorough cooling is fatal to their coherence. Similarly, it is not well to load hot briquettes of tarry or oily binders in the bin; the heat from the interior of the briquettes passes back to the semi-cooled exterior, the skin of binder is melted, and the briquettes adhere to each other, rendering loading extremely difficult and causing a large proportion of breakage. The permissible storing temperature of carbonized briquettes made of water-soluble material is much higher, but it is none the less advisable to keep such temperatures low. Principles of cooling may, therefore, be said to be a necessary study in all classes of fuel briquetting. In most of the smaller plants cooling conveyors carry off the briquettes from either presses or carbonizers, the conveyors being constructed of a woven wire belt which give access of air to all sides of briquettes. Considerable room and slow travel is necessary for such an installation. In order to save room, the larger plants, where cooling is used at all, have in general adopted some method of series conveying; that is, a series of conveyors are installed one above the other, the travel arranged so that the briquettes passing alternately from one end of the apparatus to the other receive the maximum of cooling effect in a minimum possible ground space.

At most of the installations designed and built by the C. T. Malcolmson organizations cooling is done on a conveyor built of Link-Belt malleable chain. These conveyors are frequently of very large size and travel at great distances—especially when serving the product of the Rutledge presses.

An excellent cooling table is that installed at the Canadian

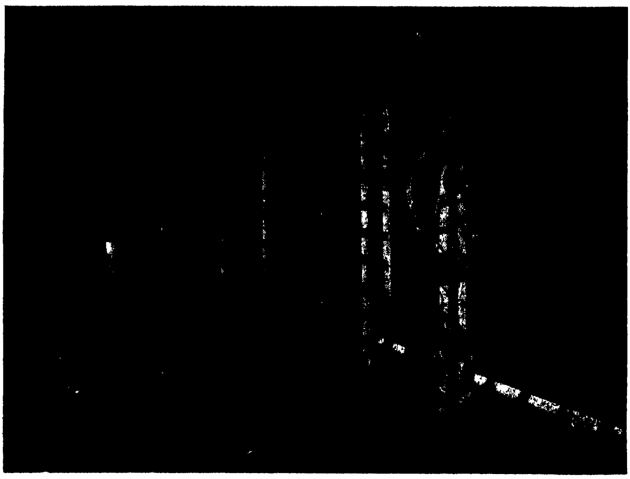

Fig. 117.—Briquette Cooler at the Plant of the Canadian Pacific R. R. Co., Bankhead, Alberta.

Pacific Briquetting Plant at Bankhead (Figure 117). This table consists of a series of endless steel plate conveyors between 6 and 8 feet wide. Similar tables have been built from 40 feet up to 130 feet between centers. When near the end of the top layer of plates the briquettes are dropped and carried backward on the reverse side of the same plates, thereby eliminating waste travel. This operation is repeated on each set of plates until they are cool enough for storing.

After cooling, briquettes are often then sent by elevator to the top of bins and are dropped into the bin along "fish ladders," a step arrangement whereby the briquettes drop from step to step on their way to the bottom of the bin. Especially is such an arrangement desirable in the case of the oil briquettes not carbonized.

A special air cooler, designed by J. B. McGraw of the General Briquetting Company for the Port Stanley Nukol Company, is illustrated in Figure 118. The single arrows denote the direction of the coal after it is discharged into the cooler at A. The double arrows denote the directions taken by an air current driven through the apparatus by a blower in such a way as to pass through the moving hot briquettes. The apparatus consists of a cylindrical shell M with an interior air pipe N. Within the space between the two cylinders are set a series of baffles, perforated plates set at angles, while below them on the interior pipe wall side are set horizontal plates C, which trap the fine coal and screenings that pass through the perforated baffles. The apparatus, therefore, serves as a cleanser and screen as well as a cooler. Air current coming from a blower D passes through conduits E into the interior pipe N whence it passes through smaller conduits F into the body of slowly descending briquettes and, having absorbed the heat therefrom, passes to the exterior atmosphere through vents G. The briquettes fall by gravity to a base hopper H and are then picked up and carried off by an apron conveyor J.

Water cooling has frequently been used. At some plants briquettes are loaded directly into the car and bins and sprinkled. The spray is often of assistance to a cooling conveyor. However, briquetting engineers avoid the use of water cooling whenever possible. The water itself, if in excess, is not of advantage in the bins and will tend to deteriorate most kinds of briquettes. Again, the sudden cooling shock, when briquettes are plunged in water, causes strain and cleavage planes within the briquettes, which manifest themselves by the cracking phenomenon known as "checking." That means a considerably lowered resistance to outside handling. In all cases air cooling, as a matter of basic principle, should be recommended, and in all cases—especially in the case of soft coal—the piling together in bins or storage piles of hot briquettes should be avoided.

CARBONIZING OR OTHER HEAT TREATMENT OF BRIQUETTES.

When briquettes have been made of insoluble binders of the organic type, such as asphaltum, ta· or pitch, it is seldom that any after-treatment becomes necessary other than cooling or storing.

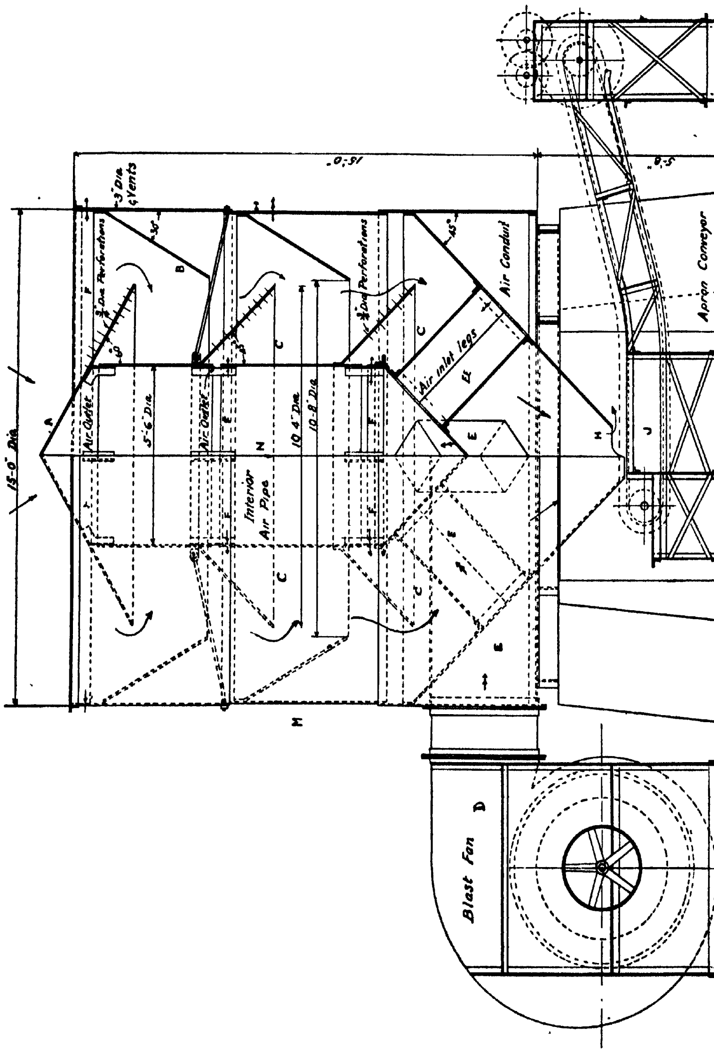
15-0" Dia
16-0"
3" Dia. 4 Vents
Air Outlet
5-6" Dia.
Interior Air Pipe
10-4" Dia.
10-8" Dia.
Air inlet legs
Air Conduit
Apron Conveyor
Blast Fan
D

Fig. 118.

There are, however, certain cases where a heat treatment is not only of advantage but a positive necessity. Such cases may be summarized as follows:

(*a*) *Fuel briquettes which require a drying operation*; that is, exposure to heat for a length of time at 250° in order to make them waterproof,—as for example the Hite process briquettes made at Lykens, Pa., and the product of the Burnrite Company at Newark, N. J. The fuel briquettes made for smelting of zinc by the New Jersey Zinc Company at Palmerton, Pa., come under this class. Although made with a sulphite liquor binder, they are exposed to heat only sufficient to dry them, as they are never subjected to adverse weather conditions, but are used immediately after drying.

(*b*): *Fuel briquettes made from soluble binders, such as sulphite liquor, molasses, wood tar and similar organic materials.* In practice such briquettes (if of 2-ounce size) are subjected to a temperature of 600° for a period of about 20 minutes (within limits: if the temperature be raised, the time is shortened; and vice versa). This operation reduces the binder to a product approaching charcoal, in effect a char in so horn-like or fibrous condition that the bond is preserved. The briquettes, although weaker than the green product prior to carbonization, are none the less fairly strong and have in instances proved quite acceptable to the market. A plant employing such methods is the Fuel Briquette Company of Trenton, N. J.

(*c*): *Briquettes, which may be of fuel, but usually of ore where lime or lime plus silica binders are employed.* Such briquettes require either steam or carbon dioxide treatment in kilns, which is spoken of at some length in Chapters XIII and XIV.

(*d*): *Briquettes formed without binder, which are subjected to high temperatures to sinter or nodulize them.* This subject is also treated in Chapters XIII and XIV, under the head of the Gröendal process.

The carbonizing oven advocated by G. J. Mashek and used by him in his designs consists of an apparatus similar to a cooling table of superposed conveyors erected in oven brick work. The oven is heated by muffle furnaces and all products of combustion pass through the oven. In addition, heated air is introduced. Each end has a sheet steel door to facilitate repairs.

Another Mashek design—the latest type in fact—consists of endless chains carrying pans with perforated bottoms, which always remain in a horizontal position. The briquettes are placed on the pans about two thick, and are not disturbed during their passage through the oven. The loaded trays are passed through a series of sealed chambers in which different degrees of temperature are carried. The briquettes are generally first subjected to 250° F., drawing out the contained moisture, after which the temperature is raised considerably in each chamber to baking or carbonizing points. Each chamber is provided with its own flue. The heat comes from muffle furnaces. The whole apparatus is provided with thermometers, gas-filled. The ovens are fired from both sides. They have inspection doors at proper intervals. They are built in capacities of 9 and 35 tons per hour.

The Malcolmson Briquette Machinery Company designed an oven and installed it at the Fuel Briquette Company's plant at Trenton, N. J. This oven also consists essentially of a series of traveling conveyors, superposed, the coal dropping down from one to the other until completely carbonized.

Great care has to be taken to prevent excess heat damaging the moving parts of any of this class of carbonizers. A drum mechanism would be vastly preferable, but it has been assumed that the treatment of the briquettes in a rotating drum, similar to the dryers previously illustrated, would be too rough and that a large amount of degradation would ensue. Doubtless, this is true in certain instances, but recent experiments by E. B. A. Zwoyer have shown that with some of the soluble binders at least it is possible to pass the resultant briquettes through rotating drum, secure excellent carbonization results and that, too, with a minimum of fines. It is understood that Mr. Zwoyer is now working upon the design of a sectionalized rotating drum type of carbonizer, and it is to be hoped at least that this apparatus may be a step in advance in the art of briquette making.

Carbonizing has not heretofore been very popular. The difficulties of maintaining the correct heat throughout the operation are enormous. True, the briquettes produced are smokeless, and are a fuel really superior in the fire to the anthracite coal from which they are made. They have no period of softening, as do the pitch and tar briquettes, but are firm from the beginning

of combustion to the end. On the other hand, they are not so tough as briquettes properly made with asphaltum binder, but are just as easy to kindle. It must be noted that the least over-heating in carbonizing destroys the char made from the binder. The result, the over-carbonized briquette, its binder being practically destroyed, cannot be shipped. On the other hand, under-carbonization achieves no purpose. The briquettes burn with smoke and odor and are easily destroyed by adverse weather conditions. The above remarks especially apply to the carbonization of briquettes made with sulphite liquor binder, but would apply quite as truly to those of molasses and, to those of wood tar.

The last operation of the briquetting plant after cooling, is the screening of the product, returning the fines to the raw material pile and running the briquettes into the bins—preferably by fish ladders. Thence they go by railroad cars or trucks to destination.

Bituminous coals, not being readily made smokeless by these methods, are not carbonized. They are however rendered smokeless by distillation processes (See Chapter XII).

SPECIAL PROCESSES OF BRIQUETTING.

There are few special processes of briquetting. Most of the so-called processes are merely patented binder mixtures. Processes which are important from the point of view of treatment rather than binder, are as follows:

1. **The Zwoyer Process** wherein the coal is dried in paddle mixer dryers, followed by mixing with atomized melted binder in similar paddle mixers, and pressed into pillow shape briquettes on special rotary presses.

2. **The Crown Process.**—This is named after the Crown Patent Fuel Works in Great Britain and is mentioned because the name Crown as applied to briquettes or patent fuel is usually associated with the hard pitch methods as described—at least in Great Britain.

3. **The Fohr-Kleinschmidt Process.**—This is now becoming popular in some parts of Germany. The pitch is pulverized to flour fineness and mixed with the coal by being discharged upon it in an atomized stream similar to the feeding of powdered coal for combustion.

4. **The Dutch Process**, wherein the valuable principle of mastication is employed, giving a far better distribution of the binding material and a tougher briquette.

The C. T. Malcolmson organization has designed and patented various machines adopted for use in briquetting, but has not patented any special process thereon. The same is true of Mr. G. J. Mashek.

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CHAPTER XI.

A CHRONOLOGY OF COAL BRIQUETTING IN THE UNITED STATES AND CANADA.

The history of fuel briquetting in the United States and Canada is herewith published to show the difficulties to be avoided in future construction. There have been many failures, but of late years the number of successful operating plants has steadily grown. The following may be assigned as the usual causes for failure:

1. Lack of Technical Knowledge.—In the early days, before the briquetting of fuel became a standard industry, many failures occurred because the industry was simply in an experimental stage. It was necessary that research be made under difficulty and loss to determine the proper course to be followed.

2. Lack of Study of Markets.—It has always been characteristic, unfortunately, of briquetting companies newly founded to lay plans for production without properly sounding the adaptability of their product to the market they expected to cover. Fuel markets in the United States vary widely in character with the locality. In the East, along the Atlantic seaboard, the people are accustomed to Pennsylvania anthracite properly sized—probably the best household fuel in the world. Such a population must have the very best of fuel briquettes to compete with the mined product to which they are accustomed. They are impatient with smoke in a briquette, they insist upon excellent binding quality and with all, demand a superior fuel at a price lower than they are accustomed to pay. It has not been easy to accomplish an answer to such demands; but to-day a large tonnage of anthracite briquettes of high quality is being delivered in the Eastern states. In the West the problem is somewhat different; the people were accustomed to burning soft coal—sized—and were eager to obtain a superior fuel. The briquetting of soft coal was recognized in the main as improving palpably the character of bituminous coal from the domestic standpoint. The population was ready to pay a premium for briquettes over domestic soft coal. The problem lay in keeping that premium within bounds and supplying the briquetted soft coal at a price the public was willing to pay. This problem, too, has been solved of late years especially in the Lake Superior district. In certain cases, too, the briquetting of soft coal slack has been found a great advantage for industrial and steam-making purposes as well as domestic.

3. Foreign Technique was tried in many instances but not found adaptable to American conditions.—It was thought that only successful practice in Europe should be copied in the early efforts to briquette American coals. In Chapter IX has been detailed the long and arduous research pursued by the government and private parties to the end that American lignites be briquetted on a large scale by the

German "Braunkohle" process. To-day but one installation exists and some little hope of this process proving adaptable on a wide scale. In the case of both bituminous and anthracite coal, methods very popular in England and Germany produced large briquettes, from one to twenty pounds in weight. With few exceptions such briquettes have not proven adaptable to the American market. It is now universally recognized that the ideal briquette for America is the one that can be handled with a fire shovel. The use of foreign binders, (and in Europe coal-tar pitch is almost universal) has produced a briquette in America too smoky and redolent of acid vapors to be successful. The most successful plants have taken the best that Europe had to offer and adapted it to American conditions.

4. *Insufficient Financing.*—With the single exception of improper sounding of market prior to putting briquettes on sale, the insufficient financing of proposed plants has been the most frequent cause for grief. Briquetting, unfortunately, looks a good deal easier to do than it is. Cheap plants, faulty in design, inadequate in performance, and poor in product have resulted very frequently where the original estimate of cost has been far too low, sometimes through complete lack of knowledge and at others through less savory causes.

5. *Wood Construction.*—Wood construction has been a cause of failure in many cases. The fire toll of briquetting plants has been extremely heavy. The lesson is now learned that where so much high temperature work is done fireproof construction is necessary. The story of many plants is: burned down—never rebuilt.

The briquetting plants of the United States, so far as can be ascertained, chronologically arranged are and have been as follows:

1872—At Port Richmond Piers, Philadelphia, Pa., E. F. Loiseau built the first briquetting plant in the United States, and while a failure commercially, it is, of course, of extreme interest as such. The binder used was of clay and the briquettes were waterproofed by a coating of shellac. A Belgian type of press was used.

1876—The Delaware and Hudson Company, in 1876, built a plant at Rondout, N. Y., which operated until 1880. Anthracite screenings bound with a gas-tar binder were briquetted for engine fuel. Excessive cost of production, the tendency of the fuel to corrode the boiler-flues, and insufficient benefit to locomotive firing caused discontinuance. After 1878 the plant was operated under the name of the Anthracite Fuel Company.

1878—In 1878 a plant was built by E. F. Loiseau at Nesquehoning, Pa., near the No. 1 or Nesquehoning colliery of the Lehigh Coal and Navigation Company. Pitch was used as a binder. These briquettes were 4 inches square. Coal from pea-size to dust was used. The product was said to be good but the high cost of production caused the abandoning of the work.

1890—In 1890, at Mahanoy City, Pa., a plant was constructed to briquette anthracite culm for engine use on the Philadelphia and Reading railway. Eighteen-pound briquettes were made, afterwards changed to 2-pound bri-

quettes. The plant was designed by the Uskside Engineering Company of Newport, England, and a Stevens press was used. The briquettes were rectilinear, trademarked with an eagle and the word "Reading" on the opposite side. The plant originally had a capacity of 400 tons per day of ten hours, but when the size of brick was reduced capacity was reduced to 300 tons. The binder was English coal-tar pitch. Abandonment was caused by failure to secure a steady, uniform supply of binder, high cost, and unfavorable results in practical use.

1892—In 1892 a very serious effort was made at Huntington, Arkansas to briquette on a fairly large scale a mixture of Arkansas semi-anthracite and bituminous coal. The binder was hard pitch and coal tar mixed. The entire mixing operation being under the patents of M. Nirdlinger controlled by the National Eggette Coal Company of New Jersey. Though the plant was not a financial success, it certainly furnished a large step in advance technically. Failure was due to trouble in preparing the coal, difficulty in obtaining the pitch, high cost, and low price available for the briquettes on account of competing coals.

In 1892 at Gayton, near Richmond, Va., the first plant was built for the briquetting of Virginia semi-anthracite slack. Mr. Ware B. Gay was the moving spirit in this plant. It was successful at first and the capacity was doubled. The foreign methods of mixing were used and the Loiseau roll press installed. Based upon the success of this plant, similar installations for briquetting anthracite dust and bituminous slack were made at Milwaukee and Chicago closely following. It is interesting to note that during the summer the Chicago plant briquetted iron ore dust with pitch binder for the Illinois Steel Company.

1896—In 1896 there was aroused a great interest in the possibilities of Texas lignite utilization through the medium of briquetting. Mr. E. T. Dumble reported at that time the installation of a small briquetting plant at Rockdale, Texas, following experiments in Europe made on this lignite, a plant which used their own process and binder for making briquettes it with a binder of hard pitch. Trouble was encountered by obtaining a sufficient quantity of pitch and a contract was made for the importation of blast-furnace pitch from Scotland. The second difficulty was in proper drying—invariable in all cases of lignite briquetting with binder and without carbonization. In October, 1896 this plant burned down.

1897—About 1897 there were manufactured at Port Morien, about twenty-five miles from Sidney, Nova Scotia, briquettes composed of coal dust and pitch 12 x 6 x 4 inches. The greatest output in one year did not exceed 500 tons. It is reported that they gave satisfaction and were used both for use in open grates and furnaces. At that time, however, Nova Scotia coals were cheap and the manufacture was not a profitable investment. It was entirely abandoned soon afterward.

1901—In 1901 the San Francisco & San Joaquin Coal Company's plant was constructed at Stockton, Cal., by Mr. Robert Schorr of San Francisco. This plant, described in Chapter IX, was destroyed by fire in 1905.

1904—In 1904, the very important work of E. B. A. Zwoyer and Rolland Zwoyer found practical application first in a small plant erected in Jersey City. Later a producing plant was set up in Brooklyn. In 1907 the Brooklyn plant was moved over to Perth Amboy, N. J., and was in operation several years. This plant obtained anthracite culm from mines of the Susquehanna Coal Company of the Lykens district. After experiments on various kinds of binder, including rosin and oil, flour and others, straight coal-tar pitch was adopted, admixed to the extent of 6 to 7 per cent. It was also found that an admixture of 6 to 10 per cent soft coal was of benefit to the product.

The coal was passed through a Zwoyer dryer, consisting, as described in Chapter X, of a chamber lined with fire-brick, shaped like a trough. The material entered at one end and travelled in a direction opposite to that of the drying coal. At a suitable point in the apparatus after the coal was well dried the binder was introduced. The binder was melted in a tank adjacent to the apparatus and was carried by pipe line to an atomizer being forced thereto by a rotary pump. The stream of binder, delivered by the atomizer, was sprayed in the trough chamber so that the binder passed as a cloud with the hot gases through the suspended particles of coal toward the up-take. As a result the moisture passed off with the furnace gases and the binder in very liquid form was thoroughly incorporated in the body of the fine coal, efficiently coating every particle. A nest of six superimposed paddle mixing troughs has been of late the usual construction. After the thorough mixing by this method the next step was pressing. A Zwoyer press, of which the "Universal" is a distinct and later improvement, was used. The briquettes were pillow-shaped. The product was loaded in barges at the storage bins of the plant. The plant was partially destroyed by fire in 1909 but was rebuilt. It was a successful commercial operation until 1911 when the property was sold by the city.

1905—In 1905 a small briquetting plant was constructed by the Semet-Solvay Company at Del Ray, Michigan. The first press was of the revolver type. Later a rotary design, built by Traylor Engineering Company, making 15 tons per hour of 3-ounce briquettes was installed. The Company used an admixture of coal and coke braize together with pitch from its by-product plant. In 1909, this Company built a plant in Detroit on a larger plan which plant is described in Chapter XII.

The year 1905 was an exceedingly important year in the progress of briquetting, especially in the far West. In that year the Allen Briquetting Plant at Pittsburg, California, the American Ajax Briquetting Company at San Francisco, Cal., and the Western Fuel Company at Oakland, Cal. (all these are described in Chapter IX) began operations, mainly on coal yard screenings and lignite. with California asphaltic pitch as a binder. Most of these plants were destroyed by fire the following year in the catastrophe that overwhelmed the West coast.

In that year, too, the Government Tests began at St. Louis, Mo., and in 1907 were continued at Norfolk, Va. At the St. Louis plant (which operated during the exposition in 1904) the equipment consisted of three briquetting units: One supplied by William Johnson & Sons, of Leeds, England; one by the American Compressed Fuel Company of Chicago, Ill., and one by the Renfrow Briquette Machine Company of St. Louis, Mo. A Williams crusher was installed, and for fine pulverizing a Stedman pin disintegrator followed the crusher in operation. Drying was done on a Bartlett and Snow direct-heat cylindrical dryer.

In the English unit the coal was delivered to the feeding platform on a Robins inclined belt conveyor. Thence it was fed by hand to a coal-feeding worm through a hole in the floor. The pitch binder was reduced to lumps by hand and fed to the pitch cracker, whence it was delivered in one-half-inch size particles to the coal in the larger worm. After the worm the material entered the disintegrator, which reduced it to the desired fineness. Thence the mix was elevated to a pug mill in which it was subjected to live steam. A Foster superheater prevented the troubles caused by wet steam at first. From the mixer the plastic mixture fell to the press feed box where briquettes were made. The press was of the revolver type (Chapter II) and hard pitch was used as a binder.

In the American plant the coal was carried by a Robins conveyor to the level of the second floor to a bin. The coal was drawn from the bin to a platform scale, from which it dropped into the boot of an elevator, from which it was delivered into a measuring box. The coal was dumped into a steam-jacketed Buffalo mixer. The binder was melted in a small tank. From the tank it was dipped by hand in the required quantity into the mixer. After a thorough mixing the mass was dropped into the feed slides of a Belgian type (Chapter II) press, making eggette briquettes. Five-ounce eggettes were delivered from the press to a short rubber belt. The capacity of the press was 5 tons per hour, but the output of the mixing device was too small to operate the press at this capacity.

In rebuilding the plant at St. Louis, after an experience with fire, a Renfrow press (see Chapter II) was installed. This machine had double the output of other plunger machines. The pressure was lower than required to make briquettes using the stiff pitch, and a softer pitch was substituted. A bucket elevator and chute with a gate were provided so that fuel mix from the disintegrator went over to the fluxer of the revolver press or to the Belgian press or to the Renfrow as desired. The briquettes made by the Renfrow press were biscuit shape—cylinders about 3 inches in diameter with convex ends from 1½ to 3 inches high, weight 8 ounces.

In 1907 a portion of the equipment used at St. Louis was moved to Norfolk, Va., including the revolver press. An improved Renfrow press was loaned to the government for continued experiment and in addition thereto a Schlickeysen peat machine was installed as well. In this case then the Government Plant again consisted of three units different from those in St. Louis. In testing on the English machine coal and pitch were weighed

out and mixed in a worm conveyor and carried to a Stedman disintegrator. Thence the elevator carried the ground mix to the fluxer of the revolver press and the briquettes were made as before. In the Renfrow No. 2 plant the fuel and pitch were ground in a Williams mill whence the mix was elevated to the hopper above the machine. The fluxing in this machine, as shown in Chapter II, was done in three pairs of horizontal steam-jacketed drums after which operation the coal was pressed.

In 1908 the English press and its equipment was moved to the Bureau of Mines permanent testing plant at Pittsburgh, Pa., but no work is reported as having been done on this plant. In addition the Bureau of Mines installed a complete German lignite briquetting plant described in Chapter IX and the work at this station was confined almost entirely to the briquetting possibilities of lignite by the "Braunkohle" process.

1905—In 1905 the Los Angeles Gas & Electric Corporation began its work in the investigation of the briquetting of oil carbon. The plant now operating is under the Fernholtz system entirely, similar to the plant of the Portland Gas and Electric Light Company, described in Chapter XII.

In 1905, too, Senator W. D. Washburn erected in Minnesota an experimental plant which made a small tonnage of briquettes from North Dakota lignite without any binding material.

1906—Mention should be made of the experiments of R. L. Stewart who formed the American Briquetting & Manufacturing Company in 1906 for the purpose of briquetting North Dakota lignites using 6 per cent of binder composed of flax sirup and rosin. The briquettes he made were of large size—2½ pounds each.

In 1906 the plant of the United Gas Improvement Company of Point Breeze, Philadelphia, Pa., described in Chapter XII, was installed.

In 1906 a very considerable advance in anthracite briquetting was made in the establishment of the Scranton Anthracite Briquetting Company's plant at Dickson City, Pa., largely through the efforts of John F. Lovejoy. This plant has operated with scarcely a break since that time. With the plant is a complete coal-tar distillation outfit whereby a refined coal-tar pitch is made for binder, together with refined tar oils, which are sold at a profit. In the plant operation the anthracite culm is received from a nearby washery belonging to the Lackawanna Coal Company. The coal is extremely wet as received, but it is bought under an extremely favorable contract. After draining, the coal is dried in a rotary dryer. The melted pitch is introduced in proper proportion and mixing continued through a series of eight paddle mixers; thence it is carried to a Belgian roll press of large diameter having an output of 30 tons of 4-ounce briquettes per hour. Latterly, a smaller briquette was substituted —about 2-ounce—and the capacity of the press thereby cut down to about 20 tons per hour. It is understood that the coal-tar pitch binder has not been found satisfactory and that the plant will operate in the future with asphaltic binder.

1907—1907 was also a year of considerable activity. The Eureka Briquette Company of Rockdale, Texas followed Mr. Dumble's experiments with the erection of a small plant at Rockdale for the briquetting of lignites. Its life, however, was not long and the quality of briquette was assigned as the reason for non-continuance. The American Lignite Briquette Company of San Antonio, Texas, purchased a press from the Klein Briquette Company of St. Louis. They were probably associated with the Company aforementioned. No great output was ever realized in this locality.

Fig. 119.—Plant of the Scranton Anthracite Briquette Co., Dickson City, Pa.

The Pittsburg Coal Mining Company of Pittsburg Landing, Cal., obtained the Allen press and continued for a short while to briquette the screenings from the coal yards of San Francisco. In the month of July the plant was burned down.

The United States Coal Manufacturing Company produced in Philadelphia, the same year, a few tons of briquettes—triangular shape and small size. This Company never reached the commercial stage.

In 1907, too, a notable attempt was made to briquette anthracite coal dust by German and Belgian methods. A plant was installed by the Briquette Coal Company at Stapleton, Staten Island. The coal was ground with hard pitch in a hammer mill and was thence carried to vertical fluxers superimposed over presses of different types. In the fluxers as usual the briquette mix was softened by steam. One press was of the Couffinhal type and was purchased from Schuchtermann & Kremer in Germany (see Chapter II). The other was an eggette press purchased from H. Stevens of Charleroi, Belgium. The Couffinhal press made briquettes 4¾ inches x 2¼ inches x 2½ inches weighing 1½ pounds each. The eggette bri-

quettes of the Belgian press weighed 5 ounces. The total capacity of the plant was 120 tons per day. In 1909 the plant was moved to Murphysboro, Ill., and operated on slack coal of the Big Muddy Coal & Iron Company. The plans for this plant showed the slack coal conveyed from the tipple to a Ruggles dryer. After being dried it went to a Williams type mill. The dust was elevated to a bin and thence drawn into a Trump measuring machine where it was mixed with the binder. The mix was then elevated to a heating and mixing tank and thence went through the presses as above described. The plant was later taken over by the Knickerbocker Briquette Company and was destoyed by fire in 1911.

In this year Mr. G. J. Mashek designed a plant for the D. Grieme Coal Company, which was installed at the foot of West 47th Street, New York City. The anthracite-dust was elevated to a bin, from which it was drawn by a conveyor arranged for constant feed, regulated as desired. This conveyor discharged into a chain-elevator, which delivered to a battery of five 18-inch dryers, (Zwoyer pattern) superimposed. The material was carried through these dryers by means of paddles. The temperature of the gases from the dryer rarely exceeded 212° F. Thence the material went into an elevator and was dropped into a 36-inch Williams pulverizer, and crushed to 12 mesh. From the pulverizer the material went to another series of mixers and coolers similar in construction to the dryers. The tar-pitch binder was here introduced by means of a pump and pipe valve so arranged as to deliver a definite quantity of pitch. From the last mixer the material dropped to an elevator to the second floor which discharged it on a belt conveyor, which delivered the material to the press hopper. The press was of the Mashek type (Chapter II) and discharged the briquettes into a perforated-pan conveyor, which conveyed them to the briquette bin. The briquettes while in this conveyor were subjected to a heavy spray of water in order to cool and clean them. The pitch melting tank held about 22 tons of pitch. This plant required about 125 horsepower to turn out 10 tons per hour. In 1909 this was taken over by the Economy Coal Company. The operation of this plant ceased in 1912.

During the same year the National Fuel Briquette Machinery Company established a briquette factory at the foot of Court Street, Brooklyn. The plant was designed by Robert Devilliers, who is well-known in briquetting circles, because the American modification of the Belgian press has generally been known as the Devilliers' type. This Devilliers press was installed at this plant. The plant consisted of a series of mixers wherein anthracite culm and coal-tar pitch in proportions of 95 to 5 were mixed and passed to a vertical fluxer where the steam treatment was given prior to the pressing. The press was located immediately below the fluxer. The briquettes were sold in the Brooklyn market for domestic purposes and to some extent for stationary boilers. The capacity was 6 tons per hour and the briquettes weighed 2 ounces each. Work ceased in August, 1913, because of expiration of lease. During operation the plant was used extensively in experimental work on Dakota and Texas lignites. The binder used was hard pitch.

In the same year (1907) the activities of the Renfrow Machine Company, who had supplied the machine as above noted for the government testing plants at St. Louis and Norfolk, found expression in the establishment of two plants—the Western Coalette Fuel Company of Kansas City, Mo., briquetting Arkansas semi-anthracite screenings with coal-tar pitch, and the Rock Island Coal Mining Company at Hartshorne, Oklahoma, where the briquettes were made from bituminous slack bound with water-gas pitch. The plant of the Western Coalette Company was abandoned shortly after it started. In detail it resembled very much the Renfrow unit of the Government Testing Plant, previously described. The Rock Island Company purchased the Renfrow press that had been used at the Government tests at Norfolk. This plant had a successful operation for three

Fig. 120.—Breaker (at centre) and Briquette Plant (at left) of the Canadian Pacific R. R. Co., Bankhead, Alberta, Canada.

years, selling the product under the trade name of "Carbonets." The prolonged strike and economic features affecting the raw material caused the cessation of operation in 1911. This plant, too, resembled very much the Renfrow unit at the Government Testing Plant but careful consideration was given to the problems of construction, binder, and market conditions and the plant can safely be called a commercial success.

By far the most important advance in fuel briquetting to date was made the same year in the establishment of the famous Bankhead briquette plant of the Canadian Pacific Railroad at Bankhead, Alberta, Canada. This plant was constructed under the direction of E. B. A. and Rolland Zwoyer and it operates under their patents. Since its installation the plant has been in continuous operation and so continues to-day. A brief de-

scription is as follows:—The dust from the breaker is conveyed to a bin, from which it is taken by a scraper to a bin in the briquette plant. It then passes through a crusher and is elevated to a battery of six mixers, arranged in series, where it is heated by means of the hot gases from the mixer-furnace, which enter the mixers through flues in the sides. The pitch is atomized and mixed with the dust as it passes through the mixers. As soon as the mixture reaches the end of the last mixer it is conveyed by an elevator to the press and briquetted. The press is similar to the Zwoyer type used at Perth Amboy. The briquettes are carried by a belt conveyor to the cooling table, and are carried back and forth the length of the table seven and three-quarter times, finally dropped into the briquette conveyor, which carries them to the briquette bins in the breaker. From these bins the briquettes are loaded into gondolas or by a Victor box-car loader into box cars.

1908—In 1908 the Northwestern Improvement Company installed at South Takoma, Washington, an experimental briquetting plant designed by R. C. Hills of Denver, Colorado. In this plant Mr. Hills retorted the coal and recovered the gas and tarry products. The coal product is then briquetted on a special plunger press, designed by Mr. Hills. The project was abandoned on account of lack of capital.

In 1908 the first experimental briquetting plant was built by the Lehigh Coal & Navigation Company at Lansford, Pa. The plant consisted of a Bartlett & Snow rotary dryer, a Damon air separator, a pitch crusher, mixing tower, press, and accessories. The press was of the Devilliers type and made egg briquettes 1½ ounces in weight. In 1909, after 6,000 tons had been marketed, the plant was destroyed by fire. In 1911 the plant was rebuilt and operated along the following lines: The culm was dumped into a track hopper and elevated to a drying plant, consisting of two 30 feet by 6 feet Vulcan single-shell rotary kiln dryers. The dried culm was then run over four sets of Newago vibrating screens. Four Damon air separators were under the four sets of screens, and the sized culm from each set of screens went to each separator. The refuse or slate from each separator was discharged into an overhead steel bin, and thence to railroad cars. The purified culm from each separator went by screw conveyor to a 50-ton storage bin. From the storage bin the culm went to the mixing house, where the binder was added. Coal-tar pitch was cracked to pea and dust size in a set of rolls. The cracked pitch went to a pitch measuring device, which fed the proper amount of pitch to a squirrel-cage pulverizer. This machine pulverized the cracked pitch, and fed it by screw conveyor together with a measured stream of culm from the belt conveyor. The dry mixture of pitch and culm was conveyed to the briquetting building and elevated to two vertical fluxers. Here the mixture was heated with superheated steam and the heated mixture was fed to the presses. The briquettes went directly from the presses to the bin, and thence they were loaded into cars. In 1915 an important change was made in that the Dutch process was installed. The description

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Fig. 120.—Breaker (at centre) and Briquette Plant (at left) of the Canadian Pacific R. R. Co., Bankhead, Alberta, Canada.

years, selling the product under the trade name of "Carbonets." The prolonged strike and economic features affecting the raw material caused the cessation of operation in 1911. This plant, too, resembled very much the Renfrow unit at the Government Testing Plant but careful consideration was given to the problems of construction, binder, and market conditions and the plant can safely be called a commercial success.

By far the most important advance in fuel briquetting to date was made the same year in the establishment of the famous Bankhead briquette plant of the Canadian Pacific Railroad at Bankhead, Alberta, Canada. This plant was constructed under the direction of E. B. A. and Rolland Zwoyer and it operates under their patents. Since its installation the plant has been in continuous operation and so continues to-day. A brief de-

in proportions of 95 to 5. The coal, on being received, was subjected to a temperature of about 900° F. in a special machine to drive off the part of the volatile constituent of the coal, thereby decreasing the smoke in burning. The coal, too, was thus rendered more friable for the crushing operation that followed. The coal and the pitch were ground separately and mixed cold in a mixing machine. Thence the mix was raised to a heater and heated for 2½ minutes; from here the mix passed to a Ladley press (see Chapter II) of a capacity of 16 tons per hour. The plant was destroyed by fire in 1911 but was rebuilt in 1912 and operated for a short time.

1909—In 1909 there was a considerable activity in preparations for briquetting throughout the country. In the East, the Coal Compress Company installed a small plant in the coal yard of Messrs. Downing Brothers in West Philadelphia, under what is known as the Giles patent. The Giles process simply involves a peculiar binder. The composition consisted of a hot paste prepared from common flour and water and carried in a hot solution of iron sulphate or copperas. The use of the iron sulphate seemed to impart a hard surface and a dustless quality to the coal briquettes. The plant produced about 500 tons of briquettes in 1909, which were largely given away to introduce the process. No further operation after this year was recorded and it may be presumed that the costs were too high to justify continuation.

An important installation in this year was that of the Detroit Coalette Fuel Company in Detroit, Michigan. The fuel briquetted was Pocahontas coal. The plant was installed by the Renfrow Company and was one of the most successful of the installations of this Company. The press used was the latest improvement of the Renfrow (see Chapter II). The capacity of the plant was 8 tons per hour. Hard pitch was used, being ground and mixed dry with the coal, consequently passing through the steam treating cylinders of the Renfrow press. In general the layout of the plant was similar to that of the Rock Island Coal Mining Co. of Hartshorne, Okla., previously described. The briquettes weighed 8½ ounces. The plant went out of operation about 1915.

The same year the Rutledge & Taylor Coal Company of St. Louis put in a small testing plant at Livingston, Ill., under the auspices of the New Staunton Coal Company. The primary object of this plant was to try out the then recently invented Rutledge press of Gustave Komarek. The plant, first installed for intermittent operation, was later (as the press had proved its worth) placed on a continuous basis by Roberts & Schaefer Company of Chicago. The plant operation began with a flight conveyor which carried fine coal from the tipple to a 100-ton storage bin. Above this bin the fines passed through a screen. The oversize passed through a grinder and the ground material returned to the bin. The sized coal went to a Trump measuring device, set according to the requirements of the press. The pitch binder was broken up on the platform, weighed on platform scales, and fed into the pitch cracker, all by hand. The pulverized pitch was delivered to the mixing apparatus by conveyor. The pitch was mixed

with a small percentage of coal and ground in a pulverizer. This mixture was delivered by elevator to a hopper feeding the Trump measuring device underneath. The Trump machine delivered the proper proportions of binder and coal to a long horizontal mixer, and delivered the product thoroughly mixed to an elevator, which carried the mixture to the vertical fluxer. A special fluxer, known thereafter as the Rutledge, was developed at this plant and worked successfully. The installation of the Rutledge press, proved successful. The press made briquettes from the mixture delivered from the fluxers. The capacity of the press at Livingston was 32 tons per hour at eight revolutions per minute. Briquettes were cylindrical in shape with spherical ends 3¼ inches in diameter, were about 3 inches thick, and weighed 16 ounces. The briquettes from the press dropped on a set of grizzley bars over which they slid to the cooling belt. The cooling belt was of steel-woven wire and the briquettes remained on this belt a sufficient time to allow them to cool. This belt delivered the briquettes to a 150-ton storage bin. Briquettes were loaded out from the bin by a chute.

In this year the Standard Briquette Fuel Company put into operation a plant on the outskirts of Kansas City, Mo., under the supervision of the Roberts & Schaefer Company of Chicago. The briquettes weighed 16 ounces. The plant produced 150 tons daily with double shifts of ten hours each. The material used was Arkansas semi-anthracite screenings and coal-tar pitch in the proportion of from 95 per cent screenings and 5 per cent pitch. If the coal arrived without having encountered rain or snow in transit, it went directly to the raw coal bin. Should the coal be wet, it would go to a rotary dryer of ample capacity. The coal from the dryer was taken to the raw coal bin by elevator. The raw coal was carried from the bin on a belt and discharged into a storage bin inside the briquetting building. At the bottom of this bin was an automatic scale registering the weight of the coal as discharged. This scale discharged into a closed hopper. When the hopper was full the coal prevented the swinging bottom of the scale from operating. The pitch was unloaded on a platform at the back of the briquette building. On this platform was the pitch cracker. The cracker was fed by hand with pitch previously weighed, and the ground pitch was taken to the charging floor in the building by conveyor. The fine, thoroughly mixed material was delivered to a vertical fluxer over the press (as described in Chapter X) and fluxed with steam. The steam was superheated. The fluxed mass was discharged to the feed box of the press, where the mass was agitated while cooling, and the dies filled. The original press known locally as the Misner press was of the Couffinhal type (see Chapter II). The briquettes fell from the press to an inclined grizzley which discharged them to the cooling-belt conveyor. This conveyor was of woven steel wire and ran from the press to the storage bin. It delivered the briquettes at the discharging end at such a speed that the briquettes had time to cool and could then be handled mechanically. In 1912 the Standard Briquette Company was

redesigned and enlarged by the Malcolmson Briquette Engineering Company to accommodate a Rutledge press. It has produced from that time on 30 tons per hour of 10-ounce briquettes. This plant has always been considered a success technically and financially. Both the foregoing plants were laid out by Mr. C. T. Malcolmson.

In this year the Coal Briquette Machine Company at Oshkosh, Wisconsin, put a plant in operation in that city. This plant seems to have been a characteristic Couffinhal system plant and its drying, mixing, and pressing operation were in accordance with the best German practice. Operation started on anthracite dust mixed with 4 per cent coking coal slack and 8¼ per cent hard coal-tar pitch binder. Later the operation undertook the briquetting of bituminous coals by the same process. The press was a Couffinhal type and made two sizes of briquettes—10-ounce and 1¾-pound. The capacity was 3 to 4 tons per hour. Operation is not recorded beyond 1910.

Another important installation began operations this year; namely, the Stott Briquette Company of Superior, Wisconsin, also a successful commercial operation having been in operation ever since. This plant was designed by G. J. Mashek, using the Zwoyer method of preparation and mixing. The coal used is anthracite and bituminous slack obtained from the coal yards and docks on Lake Superior. These screenings are unloaded into a concrete bin under the track; thence they are taken to a receiving hopper or to the storage ground. From the storage ground they are taken to the receiving hopper. From the receiving hopper the screenings go to a pulverizer in the main mixing building. After crushing the screenings pass through a series of Zwoyer dryers and mixers (as in the Bankhead plant). At the end of the sixth mixer the mixture is passed to a briquetting press of the Mashek type. Latterly, hydrolene or asphaltic pitch has been used as a binder. After pressing, the briquettes go through a cooling room and thence to the bins. The briquettes are pillow-shaped and weigh 2¼ ounces each.

In 1909 the Black Diamond Briquette Company of Dallas, Texas, took over the business of the Texas Briquette Fuel Company which had been organized the previons year but had never produced. The object was the exploitation of a briquetting process known as the Mannewitz. A small quantity of about 200 tons was produced on a brick press in 1909. Arkansas semi-anthracite slack was used as raw material. The plant was destroyed by fire the same year.

1910—In 1910 a plant was established by the Coal Boulet Company at 57th Street and 12th Avenue, New York City. The organizers were Messrs. Martin and Alexander, who organized the company and imported the machinery from France. The process was supposedly secret. As a matter of fact, coal-tar pitch was used, being distilled from tar in pitch kettles. Thence the coal and coal-tar pitch were mixed in horizontal mixers and the mixture was passed to a vertical fluxer. At the base of this machine the mixture was divided into two equal parts and fed to

two small rotary Belgian presses. Two-ounce eggettes were made. An interesting feature of this plant lies in the fact that its operators are considered to be the first of the retail coal dealers of New York to use motor truck delivery. The plant had no railroad siding and the expense of handling thereby proved extremely high. Operation by the company ceased in 1914. The Tepper Fuel Company operated for a while at this locality endeavoring to produce a briquette with sulphite pitch binder followed by carbonization. Some excellent briquettes were made but the plant was not commercially successful. In 1918 the site was taken over by the General Briquetting Company for a custom and experimental plant for general briquetting research. A portion of the plant was devoted to metal briquetting and is discussed in Chapter V. A portion was devoted to laboratory which is discussed in Chapter XV. The coal operation was revised and improved and the "Universal" press was developed there. Very successful briquettes were made under the Dutch process. The scale of operation was too small, the location too unfavorable for financial profit as a coal briquetting operation.

The coal operation was as follows: Coal was delivered in trucks and dumped into an elevator boot through a set of grizzley bars. The elevator carried the coal over the storage pile where it was distributed by a tripper. An underground belt under the storage pile carried the coal as needed to another elevator which took it into the plant. There the coal was dried in a direct-heat rotary dryer, and screened—the oversize going to the boiler—and the fine size to the feeding bins. Asphaltic pitch (hydrolene) was used as binder. It was brought to the plant in packages, broken by hand, and melted in a tank by means of steam coils. The melted binder was pumped from the tank to a valve where it was admitted into the horizontal mixer, where it met the coal. A heat was applied to the coal by means of a gas flame at the head of the mixer. The mix went from the mixer to the masticator (the essential machine of the Dutch process) where thorough grinding and compounding gave the mix homogeneity. From the masticator material passed down a vertical steam fluxer and was delivered to a "Universal" press which turned out 2-ounce pillow-shaped briquettes at a rate of 10 tons per hour. The raw material was obtained from the coal yards of the city and the product was distributed by the same firms.

During this year another one of the Renfrow group of briquetting plants went into operation at St. Louis, Mo., under the auspices of the Anthracite Coalette Fuel Company. It is understood to have been similar in description to the Detroit Coalette Fuel Company plant in Detroit. The production in 1911 amounted to 5,000 tons. The mixture being 91½ per cent Arkansas anthracite and 8½ per cent coal-tar pitch. No operation is reported subsequent to that year.

In 1910 a very serious effort was made to bring into the field of usefulness the graphitic coals that occurred in the anthracite beds of Rhode Island. Rhode Island coal is so exceedingly hard that it has never made

any progress as a fuel in the commercial sense—either domestic or industrial. It was recognized that if this coal were ground and mixed with a proportion of coal-tar pitch or oil, that the missing volatile constituent which had been removed by nature would be restored; and the coal could then take its place in the front rank of fuels; and that, too, in a region where fuel was scarce and shortages frequent. Obviously the best way to secure such a result was to grind the coal, mix with the coal-tar pitch and oil, and briquette. The Rhode Island Coal Company installed a plant about 1910 and both G. J. Mashek and the Zwoyer brothers were associated in the design and construction thereof. Coal brought up from the mines was crushed fine and passed through trough-like dryers containing paddles characteristic of the Zwoyer process. These dryers were arranged in a series of six and in the second one the binder was introduced into the dry coal. A spray was used disseminating the melted binder through the coal as it passed through the paddles. From here the mixture went to a press similar to the Mashek design and pillow-shaped 2-ounce briquettes were delivered. The product was excellent and found a ready sale; but troubles in reference to the title to the mine led to litigation which finally drove the company to bankruptcy in 1912. Operations were never resumed. In 1912 it was bought by the Portsmouth Coal Mining Company but they did not operate.

1911—In 1911 the United Collieries Company installed in Seattle, Wash., a plant which used their own process and binder for making briquettes of Washington bituminous coal slack with some admixture of available lignites. The binder was a special compound, consisting of 4 per cent to 5 per cent coal-tar pitch and about 1 per cent of gluten—probably a flour waste. The capacity of the plant was 200 tons per day. The press used was of the Belgian type and made an eggette of about 4½ ounces. The design and layout was made by Mr. N. L. Tooker. Operation ceased in 1915.

In 1911, too, the plant of the National Fuel Briquette Machinery Company at South Brooklyn was moved to Phoenix, Md., and installed under the auspices of the American Coal Boulet Company. Briquettes were made at the rate of 10 tons per hour on the Devilliers press, the briquettes weighing 1½ ounces each. Raw material was Georges Creek coal and the binder was asphaltic pitch. In 1915 the plant was taken over by the Belgian Coal Fuel Company. Plant ceased operation about 1917.

1912—The Coal briquetting plant of the Berwind Fuel Company was designed by C. T. Malcolmson and built by the Roberts & Schaefer Company of Chicago. It is located on the south end of the Berwind dock at Superior, Wis. The coal screenings are delivered to a raw coal tower by a locomotive crane. The tower runs parallel to the raw coal conveyor, to which it delivers the fine coal through an automatic feeder. The tower contains a roll crusher and all coal is reduced to three-fourth-inch size. Coal is then brought to the briquetting plant on a conveying

belt. Thence the coal passes over a magnetic separator to remove tramp iron and thence by conveyor to the raw coal storage bin. This bin has a plunger feeder underneath, which feeds the coal to another conveyor which delivers the coal to the dryer hopper. One Ruggles-Coles, double-shell, rotary dryer reduces the moisture to the proper proportion. Its capacity is 40 tons per hour of dried coal with 7 per cent initial moisture in the coal. A plunger feeder under the hopper feeds the dryer, excluding air from the in-take. The dried coal is conveyed from the dryer to a storage bin. The

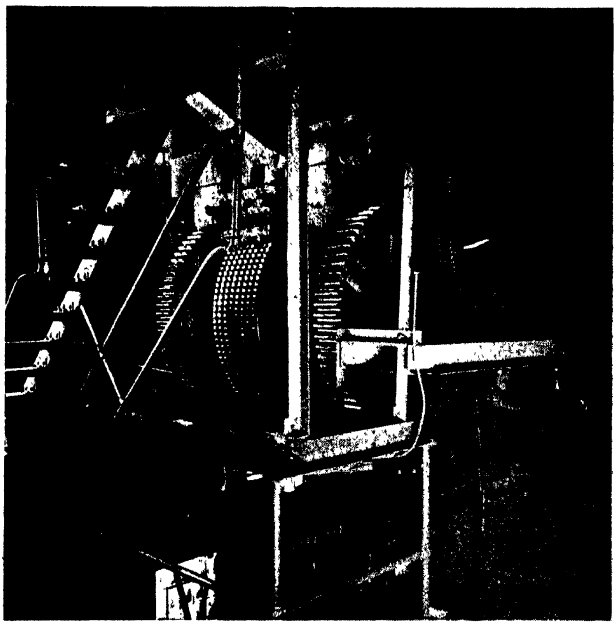

Fig. 121.—Komarek Press at the Berwind Fuel Co. Plant, Superior, Wis. (Rutledge Press in the Background).

pitch, used to make large size briquettes, arrives at the plant in box cars. The pitch is hoisted into storage in a drop-bottom bucket. It is broken up by hand as required. A small Williams mill pulverizes the broken pitch to proper fineness, together with a small amount of coal dust. The crushed pitch mix is delivered by belt to a steel hopper in the mixing platform. On the mixing platform the coal and pitch are proportioned by means of pan conveyors, serving as feeders. The coal and binder are then discharged into a large Williams crusher, which serves both as grinder and mixer. Further mixing is obtained in a steel paddle mixer,

which delivers the mix to a bucket elevator, from which it is discharged into the Rutledge fluxer. The coal and binder pass down the fluxer, through which superheated steam is introduced, liquefying the pitch and thus fluxing the mix. From the fluxer the heated mixture is conveyed directly to the feeding hopper of the Rutledge briquetting press. The fluxer holds, normally, about 7 tons. The briquettes formed on the Rutledge press are cylindrical in shape with spherical ends, and weigh 13 ounces. The letter "B" is stamped on one end as the Berwind trademark. The press turns out 38 to 39 tons per hour. The briquettes are discharged on a perforated chute which delivers them to the cooling belt. All of the fines and damaged briquettes pass through this chute into a flight conveyor, delivering into the elevator that carries the dry mixture to the fluxer. The cooling belt passes from in front of the press to the transfer building. The briquettes are sufficiently cooled thereon to be loaded directly from the end of this belt into cars, if desired. Briquettes are taken to storage from the transfer building by conveyors. The briquettes pass from the conveying belt to a stacker, which operates across the dock on tracks alongside the belt. The large briquette made by the Rutledge press proved entirely satisfactory for the purpose for which it was designed. On the other hand, a very considerable demand arose for the small size briquette similar to stove coal, especially for use in the domestic field. After due investigation the Berwind plant added to their equipment the necessary machinery to make small briquettes by the Dutch process. Two large masticators, operating in parallel, and under-driven, were installed. Petroleum residuum, 140° melting point, was adopted as the binder. The mixing, prior to the mastication, was along lines similar to those already described. From the masticators the mix proceeded through Rutledge fluxers and was then made into briquettes in a Komarek press with stationary liners (see Chapter II), and this press has operated satisfactorily. The demand for the small briquette was large, and the excellence of the briquette produced led to a large and increasing business which persists to-day.

In 1912 the Eggette Coal Company of Trenton, N. J., established a plant operating under the Giles process already described. Anthracite culm was brought from the mines as raw material and the Giles patented binder was used. Mixing was done in horizontal mixers and the material pressed in roll presses. An unusual feature lay in the fact that the briquettes were pressed cold. After pressing, the briquettes were subjected to a temperature of about 200° F., which dried them and rendered them presumably water-proof. There was a good sale in Trenton for the product. In 1915 the plant was taken over by the Specialty Engineering Company, but ceased operations the following year, and remained idle until entirely renovated in 1916.

In this year, Mr. A. Pagenstecher, Jr., organized the Fuel Briquette Company, which took over the plant, remodeled it, and began the first serious commercial work in the manufacture of briquettes in America using a sulphite liquor binder. The plant was redesigned by C. T.

Malcolmson, whose Company undertook the contract for reconstruction. Anthracite culm brought from the mines is dried in rotary dryers. It is mixed with about 8 per cent sulphite liquor solution (50 per cent). The mix is passed through a vertical fluxer under steam and goes thence to an eggette press of the Belgian type. After pressing the briquettes are passed through a traveling belt carbonizer and the product is rendered smokeless and waterproof by means of carbonization at about 600° F. However, in addition thereto a large portion of the briquettes are packed into 20-pound paper bags and sold without carbonizing. The plant has been a success.

In November, 1912, the Virginia Coal Briquetting Company began operations in Richmond, Va., using the Hite process. The raw material consisted of 75 per cent Virginia semi-anthracite and 25 per cent Pocahontas coal. The binder consisted of crude oil with a small percentage

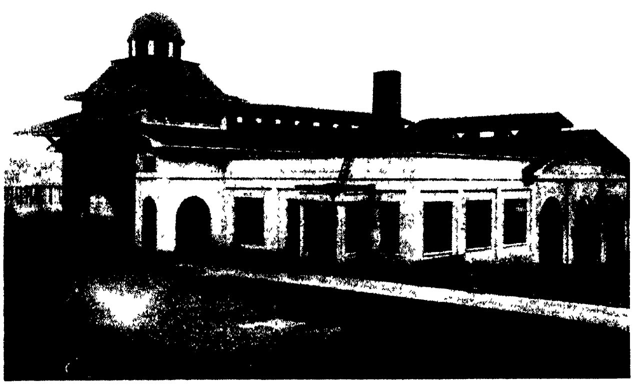

Fig. 122.—Briquetting Plant of the Portland Gas and Electric Co., Portland, Ore.

of starch emulsified by water. This was the original Hite formula. In the plant the coal was dried in rotary dryers and mixed with the binder in a horizontal mixer. The binder was emulsified in tanks by agitators and carried over to the horizontal mixer where it was mixed with the coal in proportion of about 3 per cent. After the mixing the material was pressed into briquettes in a roll press of the Belgian type, and the briquettes were submitted to a temperature of somewhat over the boiling point of water on a traveling belt. This baking process sufficed to waterproof the briquettes. The plant ceased operation about 1915 through the technical and financial difficulties.

1913—In 1913 the American Coalette Company established a plant at North 21st Street, Philadelphia, Pa., for the manufacture of anthracite

briquettes using a binder which was secret. Little is known of this Company and its methods as the process as well as the binder were guarded. The secret binder was later changed to hydrolene. It is understood, however, that Mashek mixers and presses were installed. The Company made a very good product which was sold in the Philadelphia market. It continued in operation until 1917.

About 1913 the Government Investigations, described in Chapter IX were made under the auspices of Dr. Babcock, North Dakota School of Mines, Hebron, N. D.

In this year, too the Portland Gas and Electric Company established a plant at Linnton, Oregon, which is described in Chapter XII.

In the same year the Hill Westing Briquette Co. (later taken over by the McKinlay Coal Co.) established a briquetting plant in Denver, Colorado. In the operation of this plant the coal slack was unloaded into a pit at one end of which was an elevator (chain buckets) which carried the slack to

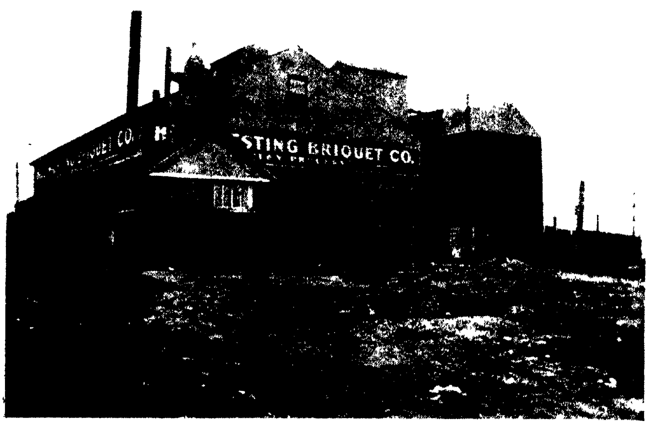

Fig. 123.—The Hill-Westing Briquette Co. Plant, Denver, Colo.

the top of rotary screens, where the coal was separated and the fines turned into bins, or into the Williams mill. The oversize was sold as boiler fuel in Denver. From the grinder an underground conveyor carried the slack to the main building. Thence a conveyor carried it into a feed bin (50 tons). This bin fed into the double Trump measurer and another conveyor took the slack to the mixer. Near the coal grinder was a pitch cracker where coal-tar pitch was ground with coal in proportion of one to four or five. This mixed product was conveyed underground and elevated to a second tank close to the 50 ton coal tank, and the contents of both tanks were fed to the proportioner and thence to the mixer, which was steam-jacketed. From the mixer the hot mix went

to two Belgian presses; thence to storage. The plant at first worked under what was called the Boley process, in which a binder of starch and chemical solution was used. This was a failure, and the pitch process above outlined, following older methods, was installed. The plant had a capacity of 20 tons per hour. The briquettes were egg-shaped and in two sizes. Lack of proper drying facilities caused some dissatisfaction with the later product and the life of the plant was not long.

1914—In 1914 the Northern Briquetting Company's plant for the carbonizing and briquetting of Dakota lignite was in operation. This plant has been described in Chapter IX.

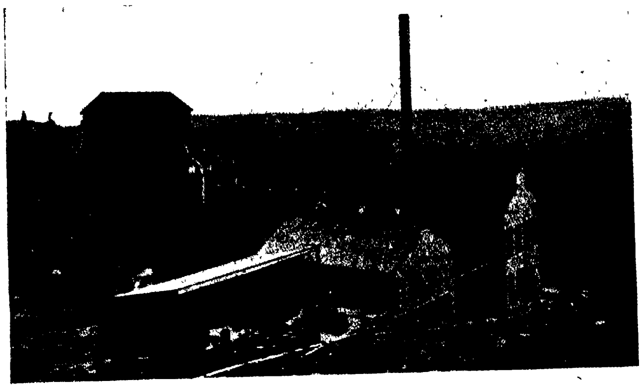

Fig. 124.—Briquette Plant of the Pacific Coast Coal Co., Seattle, Wash.

In this year, too, the Texas Nu-Fuel Company at San Antonio, Texas, established an experimental briquetting plant in that city for the manufacture of fuel from garbage and coal dust. The garbage was delivered to the plant in wagons, sprayed with creosote, and macerated in a mill. The mass was placed in a tank, where it was cooked with live steam until a homogeneous mass resulted. Under the process controlled by this Company the garbage and coal-dust were mixed in equal quantities with the addition of 7 per cent gas-tar pitch. A brick press was used, in which the mixture was briquetted, and the briquettes stacked to dry. The Canadian rights to this Company were taken over by the Oakoal Company, Ltd.; which later built a plant in Toronto but never engaged in serious operation. Other plants have been projected for this purpose in Sandusky, Ohio, and Baltimore, Md., The San Antonio plant may be considered as of an experimental nature.

In this year the important installation of the Pacific Coast Coal Company was made at Briquetteville, Wash., near Seattle. The coals of the state of Washington suffered the disadvantage of slacking heavily. The advantage of briquetting in that district was recognized, and a contract for

the plant was awarded the Malcolmson Briquette Engineering Company of Chicago. The plant has been successful and has operated ever since. The operation is as follows: The raw coal is unloaded from hopper cars through a track hopper into the raw coal bin. From the bin, raw coal conveyors carry the coal to the dryers direct or to a Williams crusher. Excess moisture is eliminated in the first dryer, and after crushing the coal is dried and heated in the second dryer. Two sem-direct heat Ruggles-Coles dryers are used. Fuel oil is used for drying the coal. The dry coal goes on a continuous bucket elevator to a small dry coal bin under the roof of the machine building. Underneath the dry coal bin an apron feeder regulates the quantity of coal required by the press and delivers this coal to the preliminary mixing equipment. Liquid asphalt binder, maintained at constant pressure and uniform temperature in a tank, is introduced by means of a Forman steam-jacketed regulating valve into the mixer containing the dry coal. The proportioning of binder and coal is under control of an operator on the charging platform. After passing through the mixers (horizontal paddle) the coal and binder pass to a Rutledge fluxer. This apparatus achieves a thorough blending or fluxing of the coal and binder and a thorough coating of the coal particles with a thin film of binder. The Rutledge fluxer consists essentially of a large chamber and two partly inclosed superimposed sections, where superheated steam is introduced into the mixture through a carefully worked out piping system. Shafts are provided with a series of paddles so arranged as to agitate and thoroughly flux the coal and binder as it passes downward through the successive chambers. The temperature of the agglomerating mass is raised at a uniform rate, and with great economy in the successive stages, owing to the partly inclosed chambers. The Rutledge briquetting press is of the same type as those used in the plant of the Berwind Fuel Company at Superior, Wis., but manufactures a smaller briquette. The briquettes are discharged from the press on a chute and go thence to the cooling conveyor. The cooling conveyor is of Link-Belt malleable chain and passes below the floor, from the front of the press to the outside of the machine building; whence it travels to the lower floor of the briquette loading pocket. The speed of the conveyor is fixed so that the briquettes may have the best possible opportunity for cooling. The surface cooling is assisted by the use of a fine spray of water. The asphalt binder comes from California in barrels. They are stripped as required, and the asphalt is charged by hand into kettles, in which it is melted.

1915—In 1915 the Delparen Anthracite Briquetting Company established a plant at Parrott, Va. The plant was designed and constructed by G. J. Mashek. It was originally designed to produce a smokeless fuel from Virginia semi-anthracite using a vegetable binder. Later the operation was changed to meet the requirements of coal-tar pitch binder. The plant had a capacity of 20 tons per hour of 2-ounce briquettes. About 1917 the binder was again changed to asphaltic pitch (hydrolene). It is considered to be in the class of successful operating plants. The coal

is dried in rotary drum dryers and mixed with melted binder in horizontal mixers in which it receives the steam treatment. The mixed flux passes to a battery of two Mashek presses, and the briquettes then pass over a cooling belt to the bins.

In this year the Pacific Gas and Electric Company established at Oakland, Cal., a plant for the briquetting of oil carbon, which was in effect similar to those at Los Angeles and Portland, as described in Chapter XII.

In 1915, too, the Lignite Fuel Company established its brown coal plant at May, California. The history of this enterprise is outlined in Chapter IX.

In 1915, too, began the experiments of the International Fuel Products Corporation with the experimental plant at Irvington, N. J., described in Chapter XII.

1916—1916 saw the establishment of the Johnson Fuel Company at Scranton, N. D., and the American Coal By-products Company at Denver, Col., whose history is also found in Chapter XI.

In 1916 the Gamble Fuel Briquette Company established a plant at Harrisburg, Pa. This plant was designed to use the Gamble patented binder, essentially sulphite liquor water-proofed by oil admixture. The plant was designed by G. J. Mashek. The coal is dried in rotary dryers and mixed first with the sulphite liquor, after which the oil was added in melted form. Sulphite liquor of the usual 50 per cent solution was used. It was originally planned that the briquettes would be carbonized at about 600°. This plant was later abandoned and the briquettes sold as they came from the press. This plant discontinued operations in 1919.

In the same year, 1916, a similar plant under the same process was erected at Richmond, Va., under the auspices of the Southern Briquette Coal Company. The plant unfortunately burned down a few weeks after it had been erected. The machinery of this plant was taken over later by the Anthracite Briquette Company, of Sunbury, Pa. an organization promoted by Dr. Gamble and his partners. This plant too, was designed, at least so far as the layout and the machinery was concerned, by Mr. Mashek. This transfer and re-erection occurred in 1913. The layout methods are entirely similar to those described in the Harrisburg plant above. The plant is now operating with a capacity of 10 tons per hour. There is no drying or baking oven. During the operation the percentage of hydrolene constantly increased and in 1920 the binder was said to be 6 per cent asphaltic pitch (hydrolene) and 1½ per cent sulphite liquor. The briquettes after cooling for 45 minutes were extremely hard. Later the use of sulphite liquor was abandoned and asphaltic pitch used alone.

In 1916 the very interesting venture was made of building and equipping a briquetting plant solely for export sales. The plant was built by the Virginia Navigation Company at Norfolk, Va., under the auspices of W. R. Grace and Company and has since come under the control of

the Pocahontas Fuel Company. Contract for the plant was awarded the Malcolmson Briquette Engineering Company. It was the largest plant erected in the country up to that time and was intended to have a capacity of 1,000,000 tons per year of briquetted and screened coal of which 300,000 tons were briquettes. The raw material was Pocahontas slack. The briquetting plant proper resembles in general the Berwind and Pacific Coal Company's installations except that the hard pitch process was used. The coal was dried in rotary drums. The coal and hard pitch is mixed in mills and the pulverized product is passed through horizontal paddle mixers to large vertical steam fluxers which softened the binder and prepared the mix for the Rutledge presses. The briquettes travelled from the press to a cooling belt and thence to storage for loading on cargo steamers. The plant was not made ready for operation till 1920 and since then operated intermittently.

In 1916 the Colonial Coal Company of Sidney, Nova Scotia, put in two plants about ten miles apart located at Sidney. Machinery was imported from England and the hard pitch method was used. The hard pitch and coal was ground in a mill, mixed, and fluxed, and pressed into 7-ounce briquettes in Belgian eggette presses. These plants are no longer operating.

1917—In 1917 there was a small briquetting plant established at Piedmont, West Virginia, by W. D. Althouse and Company of Philadelphia. This plant did not operate long because better prices could be obained for the raw coal. The coal and hard pitch binder were passed through a crusher, mixed in a pug mill and briquetted. Later, westrumite (See Chapter VI) was adopted as a binder. This plant was dismantled in 1918 and one press was removed to Rochester, New York, where it was for a short time used for experimental purposes at the plant of the Rochester Gas & Electric Light Company. The other press was subsequently sold to the International Coal Products Company of Irvington, New Jersey.

In 1917 the American Briquette Company, holders of the Hite process, established in Philadelphia a 3-ton-per-hour experimental plant for the development of that process. It may be said that the experimental side of this work had been going on for some years previously. Anthracite silt, direct from the coal washeries, was used as raw material and the binder was the Hite emulsion. The emulsion of the Philadelphia plant consisted of one-half of 1 per cent cornstarch, 1 per cent asphalt, and 6½ per cent of water. The starch and water were made into a paste and brought to the boiling point by live steam. The melted asphaltum was then introduced and beaten into the paste by agitators. The emulsion when dry is said to be an insoluble mortar. The coal was dried in a Ruggles-Cole rotary dryer, fed to a horizontal paddle mixer, where 8 parts of binder were mixed with 100 parts dried coal-dust. The mixture was discharged directly from the mixer to a Belgian roll press and briquettes made. From the press the briquettes went to a drying oven where they were distributed 6 inches deep over a screen conveyor passing through a hollow tile tunnel. Through this tunnel passed a current of air heated to 225° F. The briquettes required an hour to pass through the tunnel

and then went to the loading chutes. The briquettes made by this process are smokeless and stand water and weather well. They hold their shape in the fire and do not soften or fuse. The briquettes are not so tough as well-made asphalt briquettes and show some degradation in shipping.

1918—The following year (1918) the same Company installed a larger plant at Lykens, Pa., using the same process. The proportion of the constituents of the binder at this plant was 200 gallons of water to 140 pounds of starch and 35 gallons of asphalt, mixed as outlined above. The coal is dried in a single-shell rotary dryer. The binder is mixed with the dried culm in a split screw conveyor and conveyed to the press. The

Fig. 125.—One Day's Production at the Briquette (or Boulet) Plant of the Lehigh Coal & Navigation Co., Lansford, Pa. (Plant in the left rear).

press is Belgian type made by the Vulcan Co., and turns out pillow-shaped briquettes. From the press the briquettes are conveyed to a dryer similar to that described above. The function of the final drying is to remove excess water and to dextrinize the starch, thereby hardening and toughening the briquette as well as rendering it water-proof. The resulted briquette contains 96 per cent culm, 2 per cent moisture, one-half of 1 per cent starch, and 1¼ per cent asphalt. This plant has been successful and is operating. It may be said in passing that the Lykens Valley coal dust, being extremely low in ash, is very favorable to a briquetting project and is particularly well adapted to the Hite process.

Lehigh Coal and Navigation Co.—2nd plant.—The new plant operation is housed in a large brick building, flanked by three sidings. Viewing the

plant toward the east, the far siding to the right receives cars for briquette loading. The near siding, with elevated tracks, brings the raw coal to the plant. To the left another siding runs between the building and the oil storage tanks and receives the binder cars.

The coal dust is received from the company breakers, and the asphaltic residuum in tank cars from the oil companies. There is no other admixture. The binder receives no preparation other than melting. The fine coal is prepared with great care prior to its reception at the plant, being made through one-sixteenth-inch mesh and over a three-sixty-fourth-inch mesh, and ash content is reduced to not more than 18 per cent. The oil is bought

Fig. 126.—Plant of the American Briquette Co., Lykens, Pa.

on specification. It has 160° melting point, and about 20° penetrability. It is paraffine free, and, melted, free flowing and easy to handle. Each tank car contains a steam coil, readily attached to the steam supply line. The melted binder passes out of the car, through straining screens, (to catch any contained foreign material), to the cellar. Thence it is pumped to a header line, in which are a series of control valves, whereby any one of the large storage tanks may be supplied. The oil handling part of the operation is especially impressive and seems incapable of any further improvement. Oil can be transferred from a 35-ton tank car to the storage tanks in 17 minutes. From the storage tanks the oil is pumped as required to the paddle mixers, where it meets the raw coal. Here too the system is elastic, and though each operating unit has its own storage tank, the oil can be taken from any one of the storage tanks to any one of the mixers.

Meanwhile the fine coal arrives at the other side of the briquetting plant in hopper cars. Having passed through the wet concentration process to reduce the mineral content, it carries an appreciable quantity of moisture, somewhere between 12 and 16 per cent.

The cars carrying the fine coal are dumped into a coal reservoir below the raised track of the siding. At the side of the reservoir a drag scraper picks up the coal, delivering it to an elevator to the roof. From the elevator it is passed to a shaking screen, removing oversize. The oversize is dropped into the boiler-room bins. The fine coal is carried to the wet coal bin in the drying room—a secondary reservoir which is called upon to deliver through pan conveyors an even feed to the dryers.

The dryers are direct-heat rotary type. They are fired by a mixture of breakage and waste material from the plant, mostly broken boulets, supplemented by No. 3 buckwheat. The moisture is reduced from 12-16 per cent to 2 per cent.

In the same room with the dryers is the boiler plant, consisting of a battery of Maxim boilers, which supply steam for heating the plant and adjacent buildings, and such steam as is needed for melting oil and for direct treatment of the coal-oil flux during the preparatory process. No steam is used for power. The plant is electrically operated throughout.

From the dryer the warm coal is lifted to the dry storage bins, which have ample capacity to furnish a reserve supply for the plant. From the bins the dry coal is carried via belt to the four feed hoppers, one over each briquetting unit.

Beneath each of the feed hoppers is a short paddle mixer. An attendant sees to the feed; both the melted oil, discharged in flow from the pipe line, measured by a check valve properly set, and the coal, delivered through a gate in the feed hopper, set for correct discharge, are carefully watched From the mixer the coal mix passes to the malaxeur or vertical fluxer. The malaxeur is a vertical chest, usually cylindrical, containing shelves mounted in a vertical revolving shaft. Material passing down these shelves is treated with steam at a temperature sufficient to insure liquidity. There is one malaxeur to each unit in the plant.

From the fluxing treatment the hot flux drops into the masticators.

The three masticators are mounted on platforms, forming a line against one wall. They are 10 feet in diameter, of extremely heavy and rugged construction. It is interesting to contrast the sticky mass that emerges from the malaxeur with the nearly dry flux turned out by the masticator.

Belt conveyors carry the masticated flux to the presses. There are four Traylor Type rolls, 48 inches in diameter, with pocket molds, approximately hemispherical, seventy-two double rows, staggered. They operate between 6 and 7 revolutions per minute.

The press feed is special, and was designed by engineers of the Lehigh Coal & Navigation Co. It is a series of fingered shafts, the fingers enmeshed, calculated to break up cakes and distribute the material evenly for the feed.

Dropping from the press, the boulets encounter a shaking screen, and the "fine dust," or coal caught between the mold edges, is eliminated, together with any chance defectives. This dust is returned to the conveyor

leading to the individual feed hoppers. Thence by a series of scraper lines and elevators, during which time they are sprayed for cooling, the finished boulets are brought to a large rotary screen. Despite the rough handling there is but little loss at this point, and the boulets, now perfectly rounded, are fed into the loading pockets. In loading into the railroad cars the briquettes are again passed over lip screens in the loading chutes.

It will be noted that a very careful screening is given the entire product, with the result that the boulets when finally loaded and shipped are nearly perfect. The cars, Figure 118, are carefully inspected, and condemned if even a small percentage of broken or soft boulets are found.

This very thorough inspection results in a uniform product, of which the following is a typical report:

	Per Cent
Perfect briquettes	92.75
Cut briquettes	3.00
Imperfect briquettes	4.00
Dirt	0.25
Total	100.00

The cut briquettes are those which are sloughed in handling by the machinery. The imperfect briquettes are those which are not full pressed or not of full size.

In addition, samples are taken frequently throughout the day and tested in the company's laboratory to insure a briquette that is not only well formed and haid, but of low moisture and low ash. The average results of the chemists' tests are as follows:

Moisture	3 per cent
Ash	18 per cent
Binder	6 per cent

In 1918 a plant was established in Montreal, Canada under the auspices of the Aetna Briquetting Company but never operated.

In 1918 the Anthracite Briquette Company established a plant in Toronto, Canada, under the Gamble Process, very similar to the one at Sunbury, Pa. In 1920 this plant was acquired by H. F. Slater, President of the Nukol Fuel Company.

1919—In 1919 a Dutch process plant was established in Toronto by the Nukol Fuel Company, Ltd. Anthracite culm was obtained from the river coal operators of Pennsylvania.

The process of manufacture may be divided under the following headings: Drying and screening raw material, handling of binder, mixing of the coal and the binder, mastication of the mixture, pressing, final screenings and cooling.

The coal is quite wet, containing sometimes as high as 17 per cent moisture. The culm is handled by a locomotive crane and dumped into a hopper, from which it is carried in a bucket elevator to a large bin, and

from that conveyed to two rotary single-shell type dryers, direct-heat, 4 feet in diameter and 45 feet long, operating at ten revolutions per minute. The temperature at the end of the drum is about 250° F.

The fine coal, dried and screened, is carried to the feeder bins. The coal is fed from each bin to a revolving table, thence to the horizontal mixer, where it meets the oil binder. The oil binder is delivered to the plant by tank cars which are equipped with steam coils for melting down the contents.

Fig. 127.—Briquettes for the Bag Trade. Nukol Fuel Co., Toronto, Canada.

The oil is an asphaltic residuum, manufactured by the Imperial Oil Co. at its Montreal refinery. A belt-driven 2-horsepower Kinney pump is installed on the oil line in such a way that it can be used to pump the oil from the cars to the oil tanks, and from the tanks to the mixing device, where it is fluxed with the coal.

The capaciy of each of the oil tanks is 20,000 gallons.

The operator sets the oil valve and adjusts the gate over the tables admitting the coal in such a way as to give a mixture of 95 per cent coal and 5 per cent oil.

The dried culm and the binder, properly proportioned,, meet at the head of a 15-foot paddle mixer. Seventeen sets of paddles revolving in a horizontal trough force the mixture forward, at the same time imparting a thorough agitating and mixing effect. The viscosity is preserved and improved by the injection of a supply of live steam throughout the operation.

To complete the mechanical mixing the coal-oil mixture which, for the sake of convenience, may be designated a flux, is delivered into a vertical cylindrical malaxeur Again steam is injected into the mass, which is

kept in constant agitation by a revolving shaft carrying radial arms. Now the flux is ready for mastication. The masticator operates at eighteen revolutions per minute. It is a 10-foot diameter machine.

From the masticator the flux is elevated directly to the feed box of the press. The press proper is of the Belgian roll-eggette type.

The briquettes as they come from the press are hard but still warm. Under ordinary circumstances passing over a cooling belt 30 feet long at the rate of 30 feet per minute is sufficient to provide ample cooling. The briquettes set and are hard enough for the usual subsequent handling. For extraordinary circumstances (such as exist in extremely hot weather) provision has been made to pass the briquettes through a water-cooling system. This system consists essentially of a water tank divided by a partition into down-flow and up-take compartments.

The Company, due to financial stringency and internal troubles ceased manufacturing in 1921.

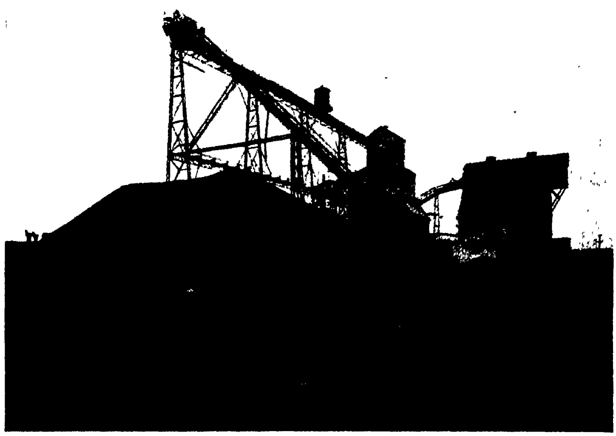

Fig. 128.—The Burnrite Fuel Briquette Co., Newark, N. J.

1920—In 1920 the first Burnrite Coal Briquetting Company's plant went into operation in Newark. The plant was designed by G. J. Mashek and modified by Mr. F. Crossman of the Burnrite Company. The coal is brought from the Pennsylvania anthracite mines and stored at the plant. Drying is accomplished in rotary dryers. The binder, which is secret, is introduced into the coal in horizontal paddle mixers and after thorough mixing is pressed into briquettes in · Mashek press. The briquettes are 2 ounces in weight and pillow-shaped. In order to make the briquettes smokeless and weather-proof they are submitted to a baking operation at

about 250° F. It is noteworthy that the press now used by this operation is using manganese steel rolls with success. The capacity is about 200 tons per day. The plant was in continuous operation until very recently, when it closed down.

Fig. 129—Plant of the Stott Briquette Co., Superior, Wis.

1921—A plant using the Dutch process, similar to the Nukol Company's plant in Toronto in all essential details, has been installed by the Port Stanley Nukol Company at Port Stanley, Ontario during 1921. This plant ceased operation soon after its completion for reasons similar to those which led to the cessation of the Toronto enterprise.

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CHAPTER XII.

BRIQUETTING APPLIED TO CARBONIZED COALS—THE BRIQUETTING OF PETROLEUM CARBON.

The Briquetting of Coke Braize.—The Fernholtz Process for Oil Carbon.—Low Temperature Carbonization of Coals—the Carbocoal Process.

The carbonization of coal has been the subject of scientific investigation for many centuries. The first great achievement as a result of these investigations was the manufacture of illuminating gas; the second, the evolution of metallurgical coke and its accompanying by-products. Two methods of carbonization have, in general, been practised; namely, high temperature—commonly known as coking—practised where high gas yield or structurally strong coke is desired, and low temperature, where the liquid hydrocarbon derivatives supply the bulk of the demand.

But for the absence of a press or other mechanical means, the production of coke might be considered a briquetting process. Coal of the required resinous content is heated in an oven. The tars are melted and the lighter ingredients thereof pass off as gas to the condensers and gas cleaners. Within the body of the distilling fuel, pitch is formed—a residuum from the distilling tar—and the carbonizing of that pitch forms a binder to the particles of coked coal. Where high quality gas is obtained, the coke is poor in quality, and not so strong as it is in cases where the ovens are run to produce a metallurgical furnace fuel. The disposal of gas coke from illuminating gas plants has always been somewhat of a problem. In all coke operations, fines are produced in quenching and handling—commonly known as braize. This braize may be regarded as peculiarly a product of high temperature methods. It is more difficult to ignite and burn than is fine coal. Used alone and without a coal admixture, it is difficult to briquette. It is highly abrasive and all machinery handling it suffers therefrom. It is cellular—difficult to dry, and, for the same reason, absorbs more binder than does coal. A small proportion of coke braize can be added to the fuel mix without causing trouble, and this is, too, a not uncommon practice. It is, however, unusual to see over 10 per cent admixture thus employed.

In the United States two noteworthy efforts have been made by prominent companies to use up their coke braize in briquette form. One of the earliest briquetting plants in the country was that of the United Gas Improvement Company at Point Breeze, Pa. The second operation briquetting coke braize was the plant of the Semet-Solvay Company at Detroit. Both companies were producers of coal tar pitch and coke fines. In the former case the coke braize came from gas coal; in the latter, from a plant making blast furnace coke. The plant at Point Breeze, as it was in November, 1906, was described by E. W. Parker in *Transactions* of the A. I. M. E. Vol. XXXVIII. At this plant the practice was to mix only two parts of coke braize to three of anthracite culm. The binder added was 5 to 7 per cent of hard coal tar. Two presses were used; both of the Belgian type, each having a capacity of 5 tons per hour.

The braize from the screen of the gas plant was discharged into a hopper, together with the coal fines. The mix was elevated into a tank, whence it was admitted through a funnel-shaped bottom to an automatic feed, from which a stream of the material was continuously poured into a dryer. The dried material was elevated and discharged through a shaking screen into a storage tank, located above the mixer. Oversize from the screen was returned to a crusher. The dried material was discharged to the automatic feed table, by which a measured stream was continuously fed into the paddle mixer. Into the feed end of the mixer was injected a continuous stream of tar pitch through a positive measuring valve. The broken tar pitch was brought from the pitch base of the tar distillery, fed into a cracker, elevated and discharged into the large steam-heated storage tanks where it was melted. From these tanks the melted tar pitch was drawn into a small steam-heated tank to which the pipe line containing the valve was attached.

The warm braize and culm, together with the melted binder, were thoroughly mixed in the steam-jacketed mixer. The mixed mass was divided into two streams and carried by mixing conveyors, allowing time for cooling, into the feed hoppers of two roll presses, purchased in France. From the hoppers the material was fed to the presses, and the briquettes were discharged on shaking screens below, which eliminated the fines. They then

passed to a woven wire belt conveyor, giving the briquettes time to cool and set, and were conveyed either to the cars or to storage hoppers, from which the buggies for the generator house were filled.

Probably because the wear and tear upon the machinery from the coke braize was too great in comparison with the benefits obtained, the plant was abandoned after running some time. It is noteworthy, however, that, technically speaking, the primary object of the plant was a success. The briquettes made were introduced in place of anthracite coal into water-gas practice and the gas produced was reported to be excellent.

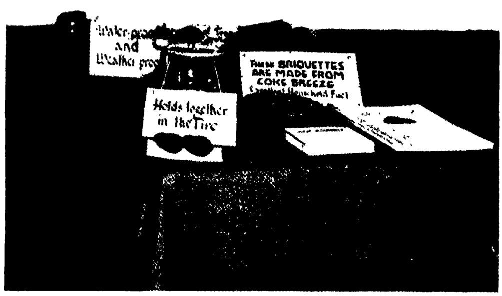

Fig. 130.—Exhibit of Briquettes Made on Belgian Press from Gas-coke Braize.

At the Semet-Solvay Company in Detroit, the hard pitch or English method was selected. It was considered to be lower in cost and better adaptable to the material in hand. The presses used were French, of the Belgian type. At this plant an endeavor was made to use as high as 50 per cent of braize. It was found that the cost of briquetting was thereby increased 50 per cent over a plant using 100 per cent soft coal. It was evident that very little could be charged against the braize in this event. On the other hand, in a district of that kind, where coals are excessively smoky, the braize had the effect of lowering the smoke nuisance. The process was conducted as follows:

The coal was unloaded into a track hopper and elevated to the coal bin. There was no preliminary crushing. The braize was dried in a rotary dryer before being elevated to the storage bin.

The coal and coke were brought together from the bins into a measuring machine, which delivered the two, mixed in any desired proportion, to a hammer mill, where the dry mix was finely ground together with the pitch. The pitch was brought from the pitch storage shed by hand and was broken into pieces of convenient size for feeding to the pitch cracker—a pair of rolls, 16 inches in diameter and 12-inch face, with small V-shaped corrugations, running at a speed of 85 revolutions per minute. These rolls crushed the pitch to about three-eighth inch. The crushed pitch was delivered into a small hopper, whence a screw conveyor delivered a definite quantity of pitch to a small belt conveyor, which in turn discharged the pitch into the hammer mill. Grinding the coal, coke and pitch together in the hammer mill mixed them thoroughly. In pulverizing coke braize, the wear on the hammers of the mill has been found too great, and a small pair of chilled iron rolls were substituted for pulverizing the coke, leaving the hammer mill for the coal and pitch. The pulverized coke, coal and pitch were delivered to an elevator, and raised to the top of the building. From this elevator the mixture went to a rotary mixer, and thence to a rotary heater, consisting of a cylinder, 40 inches in diameter and 21 feet long, set at a slight inclination. By the revolution of this cylinder, the mixture passed from the upper to the lower end and was thoroughly kneaded in an atmosphere of super-heated steam, introduced by means of a perforated pipe extending throughout the length of the cylinder. This steam was heated by waste heat from the dryer. (This steam cylinder takes the place of the vertical fluxer used in other briquetting installations, see Chapter X). From the mixing, the material was delivered via a chute to the feed box over the press. The mix was constantly stirred in the feed box by rotating paddles, and fed to the rolls through chutes. From the press the briquettes fell on a conveyor belt and were delivered to a cooling conveyor outside of the building.

The Semet-Solvay Company did not run this plant more than one year. Its operation is reported in 1909 and not thereafter. It is presumed that the price obtainable for the briquettes was not commensurate to the difficultie involved in making them.

Mr. Robert A. Carter, of the Consolidated Gas Company of New York City, spent a long time in the research covering the

production of smokeless briquettes from gas-coke braize. A series of three patents were issued to Mr. Carter in 1910-11 covering his methods for producing such a briquette. Mr. Carter advocated for use as binder the oil tar and oil tar pitch which is the residue after the distillation of the oil used in enriching water or coal gas. He mixed the braize with 7-10 per cent of the oil tar, or a lower percentage of oil tar pitch (4-5 per cent). He claimed that the "coking propensity" of a briquette made with the binder of oil tar or oil tar pitch was much greater than that of a similar briquette made of coal tar or coal tar pitch—probably due to the absence of free carbon in suspension (see Chapter VI).

The briquettes as made were placed in his patented volatilizer apparatus consisting essentially of a series of inclined retorts over a fire brick structure. The briquettes were dumped by hand into a hopper and passed through the inclined ovens. The flow down the retort was entirely due to gravity. At the base of the retort was a boot, gas-tight, and provided with a door through which the treated briquettes are removed at intervals. It was found that briquettes thus made, carried at fairly high temperatures, were smokeless and, indeed, excellent. The process, however, was never commercialized.

In Germany, the greater part of the coke braize has been absorbed by the briquette factories simply as an addition to coal—and this in small quantities. Franke states—speaking of coke braize—that "Briquetting with pitch as bond has generally proved itself to be either too dear or unsuitable." He reports, however, a method adopted by Hoepfner Brothers of the Magdeburg district in this connection. The binder used is secret—presumably—but it is stated that its chief constituent is lime. The press used is of the piston plunger type, making briquettes of 1 pound weight.

In Europe one of the first plants for the production of coke braize briquettes was in operation in 1907 at the Gas Works in Riga. The plant, though primitive, is said to have successful operation. Latterly, there has developed in Europe—and particularly in Germany—an increasing interest in the utilization of coke braize by briquetting. Certain gas plants, especially, have been

active in adapting their braize to the domestic fuel problem. Good results have been attained at the gas works at Tegel, Nuremberg and Kolberg.

At Nuremberg a briquette plant for the production of eggette coke braize briquettes has been in operation since 1912, and associated therewith was established a tar distillation plant for the production of tar oils and pitch binder. The coke briquettes contain approximately 8 per cent of binder. The heat value of the briquetted fuel is said to be practically the same as coke. The usual advantages in connection with briquette consumption obtain, especially as compared with the burning of coke braize.

The plant at Kolberg has operated successfully for the past eight years. Here the Meguin press (see Chapter II) is now in use and cylindrical briquettes measuring 6 x 6 centimeters are produced, and are meeting an increasing market, being used for steam heat and household stoves especially. Until very recently, the briquetting at this plant was conducted by means of the hard pitch process. The coke fines were mixed with 6 to 7 per cent of pulverized hard pitch.

The mixture was kneaded in a vertical fluxer into which superheated steam was passed; thereby the hard pitch was melted and the coke fines permeated with binder. Briquettes were then formed on the press. The solidity was fairly satisfactory. Lately, however, an improvement was made by the addition of 1 per cent tar oil—practically an adaptation of the Koxit process.

The Koxit process was lately developed by Regierungsrat Alexander. Alexander, in effect, added to the usual pitch binder a proportion of oil-gas tar, which was extracted from the oil gases produced for railroads.

(Compare experiments of Robert A. Carter, preceding).

A typical Koxit plant is that erected by the Royal Railroad Altona at Wittenberg.

The plant has a capacity of 5 tons per hour. The braize is screened to remove oversize, dropped into storage bins and thence over proportioning tables to the mixer, where it meets the pitch. The pitch is broken by hand, elevated to a pitch cracker, and delivered in proper proportion in pulverized form to the mixer. The pulverized pitch admixture is 5 per cent and, in addition,

there is introduced into the mixture 1 per cent of liquid binder, the oil-gas tar. The mixture of pitch and oil tar is passed through a vertical fluxer in the presence of superheated steam and then in a Belgian press is pressed into egg-shaped briquettes. The effect of the liquid addition to the binder is to fill the pores of the coke with the binding material, enhancing very effectively the cohesive value. Certainly, the coke braize briquette produced by this means, where introduced, is an improvement in texture, solidity and burning quality over the varieties made by hard pitch alone.

At the Imperial Shipyard, Wilhelmshafen, comparative tests made upon various briquettes showed that where a briquette made of 93 per cent gas coke and 7 per cent pitch showed a 15 per cent loss under abrasive tests; a sample consisting of 93.7 per cent gas coal, 5.5 per cent pitch and .85 per cent oil-gas tar showed a breakage of only 4.3 per cent. It would seem that a very good case had been made for an increased liquidity of binder in the briquetting of coke braize.

Another instance of liquid binder—and especially an illustration of the efficiency of the Dutch process—is shown in the plant of the Pernambuco Tramways and Power Company, Pernambuco, Brazil. This plant is described by Henry M. Blossom in the *Engineering and Gas Journal* for August 14, 1918. The company concerned was troubled with an accumulation of coke braize with no available market, as there was no steam-producing generator in the vicinity. They had, too, a production of unsalable tar in liquid form.

The coke braize is permitted to air-dry under cover. It is not so hygroscopic as coal, and does not require—in this case at least—the use of a special dryer. Crude tar and pitch are mixed in equal proportions in a boiler and heated. The braize and the dust are fed in proper proportions to a paddle mixer. The binder varies between 6 and 10 per cent. A better proportioning could probably be secured if the apparatus were available. From here the mix proceeds to a masticator and is thoroughly ground up and masticated. At this machine the operator adjusts the quality of the mixture by the addition of tar and moisture and brings the mass to the proper plasticity and temperature. From the masticator the mass is

fed to the press—an eggette press of Belgian type—and the briquettes are formed. At this plant the process is automatic up to the masticator, and the discharge of that machine is intermittent. This is a decided disadvantage, as it necessitates the press operation at intervals and the making of a considerable quantity of fines. The limitations of the enterprise, however, —all the material having been assembled from the vicinity—prevented an entirely continuous operation. The briquettes are 3½ inches long, 2½ inches wide and 1¾ inches thick. They are stored in shallow heaps in the open until thoroughly dried and ready for distribution. The plant requires four men for operation. The product finds a ready sale. The briquettes, despite the "homemade" character of the plant, are excellent—probably better than the majority of coke braize briquettes made by ordinary processes. The capacity of the plant is 67 tons per 10-hour day.

In Great Britain the shortage of fuel during the past few years has lead to a very considerable practical development in the briquetting of coke braize both in by-product and gas coke.

At the Teams By-product Company, Ltd., at Dunstan the braize produced in a plant of one hundred and thirty Otto regenerative coke ovens is briquetted and the briquettes are sold for industrial purposes. It is said that the same company will shortly produce briquettes for the domestic field.

At the Smethwick Corporation Gas Works coke braize briquettes are being made on revolver presses. The materials, coke and pulverized pitch, are mixed in a mill, passed to a mixer, put through a vertical fluxer wherein they are treated with superheated steam, and thence to the press. Hard pitch is added up to 8 per cent and 1¼ per cent tar is added in the mixer. (Compare Koxit process). The briquettes are 6 ounces in weight and the output of the plant is 1 ton per hour.

At the Beckton Works of the London Gaslight and Coke Co. 1½-ounce coke braize briquettes are being made on a roll press. The capacity of this plant is 3 tons per hour. Here the braize is fed direct from storage hopper to a paddle mixer, where it is mixed with dry pitch from a pitch cracker. The braize contains a considerable proportion of pea size coke. The mixture goes into an open-bucket elevator to a vertical steam fluxer, and passes

thence into the press. A very considerable abrasion of machinery has been noted at this plant. In general, and for all coke briquetting, it may be said that the admixture of at least a small percentage of soft coal or even anthracite is of great advantage, where possible, both from the point of view of preserving the machinery, and from that of the quality of the product.

Fernholtz Process for Oil Carbon—The most notable achievement in briquetting as applied to gas works is found on the West Coast of the United States in California and Oregon. Illuminating gas in this section of the country is made directly from crude oil, coal fuel not being involved. A very fine product occurs in these plants, which is locally known as lamp black or oil carbon. Largely through the enterprise of the Fernholtz Machinery Company executives, a very respectable industry has sprung up whereby this carbon is formed into briquettes and placed on the fuel market. A typical plant is that of the Portland Gas and Electric Company, Portland, Oregon, described by Mr. E. L. Hall in the *American Gas Engineering Journal.*

The process consists in cracking the light hydrocarbons into permanent gases by spraying the oil over highly heated checker bricks. The apparatus is similar to the Lowe superheater.

The gas, tar vapor and carbon evolved in the gas generator are passed through a water seal designed to remove the carbon. The gas and tar vapor pass to the assemblers and coolers. The wash water contains about 1 per cent carbon.

The Oliver continuous filter is used to separate the carbon. This apparatus consists of a horizontal cylinder, 16 feet in diameter, open at each end, built of wood. The cylinder is partially submerged in a concrete tank, which receives the carbon water. Within the cylinder are wooden strips dividing the surface into sections. The sections are covered with galvanized iron mesh and burlap in several thicknesses, and duck canvas, fastened by galvanized iron strands. Iron pipes, acting as spokes, communicate with the individual sections. The shaft is hollow. Pipes are carried in it to one end where they meet a rotary valve which controls a vacuum. The submerged section is in contact with the vacuum ports. The suction draws water through the canvas, leaving the suspended lampblack. As the drum rises from the water, the vacuum continues in effect. Air passes through the

lampblack with some drying effect. As the drum rises further, the connection with the vacuum is broken and connection with compressed air made, the latter some time before the drum is about to submerge itself again. Simultaneously, the drum comes in contact with a sheet iron scraper. Through the action of the compressed air and the scraper, the carbon is removed from the drum surface.

There are four units of this type at the Portland Gas and Coke Company's plant, each 16 feet in diameter and having a capacity of 1,000 gallons of water per minute. The units are motor driven and placed two on each side of a 36-inch belt conveyor on which the carbon is discharged.

The belt conveyor delivers the carbon to four 50-ton dryers. The dryers consist of steel cylinders 75 inches in diameter by 45 feet long, chain-driven, (each connected to a 20-horsepower motor), and direct-fired, as is usual in coal briquetting practice.

The lower ends of the dryers are connected to 60-inch exhaust fans running at nine hundred revolutions per minute, which carry off the flue gases and some carbon dust. Cyclone air separators collect the flue gas dust for return to the plant. From the dryers the carbon is discharged into bucket elevators which carry it into an overhead hopper. There are two such hoppers, each directly over a 50-mold Fernholtz briquette press. These presses are designed especially for the pressing of oil-gas carbon (see Chapter II).

The press is operated at seven revolutions per minute, producing fifty briquettes per revolution, or three hundred and fifty briquettes per minute. The briquettes weigh about one-half pound each. The plant capacity is 10 tons per hour.

The briquettes are delivered on a short rubber belt conveyor, which discharges to conveyors to the storage sheds. These consist of twelve 12-inch belt conveyors, each with individual drive, connected to lap over each other. The last in the series is set at a steep angle to elevate the briquettes to the top of the storage pile. The delivery is thus made very elastic.

The plant cycle may thus be summarized: The wash water flows from the gas generators to the Oliver filter tanks and the carbon is continuously extracted. The water, now absolutely clear, flows into the Willamette River. About 2,000 gallons of

water per minute are treated and about 100 tons of carbon recovered per day. The carbon deposited on the filter contains 50 to 60 per cent of water. In the dryers the moisture is reduced to 12 to 15 per cent, known to be the most desirable percentage. There is a small amount of oil tar in the carbon, sufficient to act as binder.

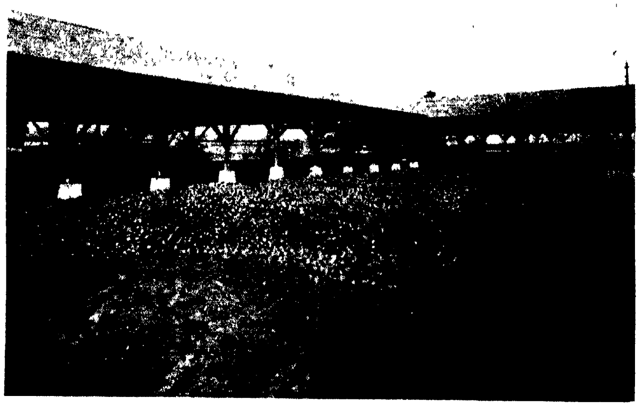

Fig. 131.—Oil Carbon Briquettes in the Storage Yards of the Los Angeles Gas and Electric Corp., Los Angeles, Cal.

The briquettes are cylinders about 2¼ inches in diameter by 2¼ inches long. They improve in storage, drying to 5 or 7 per cent water. The briquettes are carefully screened and sold in 100-pound sacks. The analysis of these briquettes by the Oregon Agricultural College is as follows:

	Per cent
Volatile hydrocarbons	8.7
Fixed carbon	87.6
Moisture	3.4
Ash	.3
	100.00
B. t. u. per pound	15,800

The briquettes sell readily at $13.00 per ton (1920) and the output is usually sold out for some time in advance.

The carbon briquettes are adaptable to all purposes that domestic coal is commonly used for. They burn excellently and with little smoke with a clear, bright flame. They hold the fire a long while and are not subject to frequent replenishment.

Low Temperature Carbonization of Coals.—High temperature carbonization has been in use for years on a large scale and the braize produced therefrom is but incidental. The *low temperature carbonization* of coal has not proceeded so far in the commercial sense, but is of tremendous interest at this time. We have already discussed low temperature carbonization as applied to wood, peat and lignite and the function of briquetting in relation thereto. Briquetting is probably a far more important adjunct to low temperature carbonization than it ever can be to the high temperature processes. For the sake of convenience, we may take the figure of 1,200° F. as the dividing line between low and high temperature work.

The early work in low temperature carbonization took the line of chemically treating the coal so that it would become self-binding in the retort, The desirability of coking at low temperatures has always been recognized.

In low temperature carbonization, there are three methods—three lines of attack as it were—at present under way in the same connection:

(1): Retorting at atmospheric pressure.
(2): Retorting at reduced pressures up to vacuum.
(3): Retorting under pressure.

Another division might be made from the method of heating. In some cases the retorts are externally heated; in others, a preheated gas at the required temperature is injected into the retort.

The bulk of the development of low temperature carbonization research has been done in England.

The present method of Coalite manufacture, designed by Mr. T. M. Davidson and operating since November, 1920, has been called a practical success. The distillation takes place in retorts or ovens 11 inches wide with vertical walls. In them are suspended two cast iron plates drilled with numerous holes. The coal charge is set between the sides of the oven and the plates. During carbonization the plates press against the coal charge and the volatile matter escapes through the holes into the space be-

tween the plates. After carbonization, the charge is released by the removal of the plates. Beneath the oven is a water-cooling chamber into which the charge is dropped after the carbonization is complete. The bottom of the oven is pivoted so that the charge can be dropped into the cooling chamber and, after cooling, it is raked to the front of the apparatus. Carbonization requires from 5 to 8 hours. One may say that, inasmuch as the distillation takes place under pressure—although small—that the coalite is—in effect—a briquette. The coal oil produced yields cresol, motor spirit, and an excellent fuel oil.

An experimental plant, wherein the above described process is at work, is located at Barugh, near Barnsley, Yorkshire, England. The plant consists of twenty retorts. The coalite is manufactured in slabs 9 feet x 6 feet 6 inches x 3 feet 3½ inches, and subsequently broken up. The plant produces per ton of Yorkshire coal, 6,500 cubic feet of rich gas (750 B. t. u. per cubic foot); 20 gallons of oil, fractionating to 3 gallons motor spirit, 9 gallons Diesel oil and 8 gallons lubricating oil; 15 pounds sulphate of ammonia; and 1,568 pounds of smokeless fuel (10 per cent volatile matter). The operation of the plant is controlled by Low Temperature Carbonization Co., Ltd.

In 1906 the famous "Coalite" patent was taken out by Thomas Parker. The basic idea was the heating of coal in the presence of steam at a temperature of about 800° F. The work on Coalite persisted for five years and involved the assistance of the best scientific brains in England. After the Coalite trials, appeared the Tozer retort of the Tarless Fuel Company. In this retort the coal is charged in concentric layers about 4 inches thick. Distillation is done as nearly as possible at vacuum. The advantages are: the distillation is effected more rapidly and the evidence seems to show that the use of the vacuum produces a much denser coke than does the retorting at atmospheric pressure. The disadvantages are increased cost, increased power consumption, and the difficulty of avoiding leakage. In America, Thomas Pritchard has reached even more striking results with a retort externally fired wherein the gases produced are circularized, a portion of them being returned to the upper part of the retort. Circulation is provided by a fan so placed as to carry the full current of gases through the charge under distillation. An ex-

cellent metallurgical coke has been made on this apparatus from Kentucky cannel coal.

Other processes similar in result are the following:

McLaurin—whereby a stream of hot producer gas is passed through a charge of coal in a retort.

Lamplough—in which steam is similarly used.

Pattison—A continuous low carbonization process wherein the fuel is carried through a heated retort on a worm conveyor.

The Del Monte System—Consisting of a screw mounted on a hollow shaft, heated internally by a row of jets from a gas pipe.

The Pringle and Richard Process—By which coal is carried on endless conveyor through a retort at 500° C.

There are, in addition, other continuous processes, as the Wood-Hall, Duckan, Glover-West, and Greene-Laucks.

In Germany there has been a very considerable research in low temperature carbonization. According to A. Thau, the continuously working revolving steel retort has been applied almost universally, probably because its design as applied to ore roasting did not offer anything new in the way of structural detail. Large quantities of fuel can be treated by this method in a very small unit.

The latest design of retort, following the rotating drum idea, is known as the Raffloer. It consists of a steel cylinder, operating upon rollers, as do the direct-heat coal dryers. At the charging end closure is made by a stationary cast iron end-plate. The opposite end fits in a stationary chamber. The entire drum is placed in a fire-brick oven. The fuel is gas, burned in Bunsen burners underneath the oven.

Within the retort are ribs, dividing the inner surface into a number of longitudinal cells, tapered toward the discharge end. In the lower part of the retort is a heavy cast iron roll, running the length of the drum, mounted on a shaft, whose bearings are set outside the drum. There are longitudinal grooves set in the roll to fit the ribs of the drum. Thus the roll, at intervals, places material in the cells under pressure.

The roll turns, actuated by the rotating of the drum, like a gear. Clearance is provided between the roll and the charging end to permit the feeding of new material into the cells. In front

of the roller the cells are closed and the material held in by an inner cylinder, or sleeve, which extends a short distance toward the discharge end.

The long cells are loaded in sequence, at the bottom of the retort, by a plunger operating through the base of a charging hopper at that point. The retort is stationary during the operation of the plunger. The heat is sufficient to carbonize the coal during the passage through the cells (about 842° F.). The distillation products pass through the stationary chamber at the discharge end, and are carried by suitable conduits to the condensers and gasometer.

At each stroke of the feed plunger the fuel in the lowest cell is forced forward and protrudes a distance out from the discharge end. The next movement of the drum carries the protruded carbon against a fixed knife, shearing it off, a coal block equivalent to a briquette.

Indeed, the apparatus is a simultaneous combination of distillation and briquetting (see Dr. Hawley's experiments—Chapter VII). At the time the plunger presses in new material from the hopper it moves the whole distilling mass in the lowest cell forward. The side of the drum, the roller and the longitudinal ribs combine to form a mold, and the operation is not unlike the open mold of the Exter press—though the pressures are necessarily far less.

The process calls for a retort 35 feet long and 100 inches in diameter. Such a retort would have a capacity of 50 tons per day. Preliminary experiment is said to have been successful, and the story of a commercial installation may come to us any day.

In general, all low temperature carbonization is subject to the following qualifications:

(a) The use of low temperature reduces the rate of heat transmission. The limit of charge thickness, figured in stationary charges, is 45 inches. Such limitation means that the initial plant cost is high as well as the cost of operation.

(b) The time required is usually long, although some of the above-mentioned methods have ingenious means for shortening the coking period.

(c) Low temperature carbonization improves, in general, the quality and strength of the cokes or carbons produced from coals classed as non-coking. None the less, the usual product, in a vast majority of cases, is a very friable, fragile product difficult of handling and unsatisfactory as domestic or industrial fuel unless special burning appliances are provided. In other words, the carbonized pitch that forms the binder of high temperature cokes is lacking—at least to a serious degree. We have seen (in Chapter IX), how it has been proposed to remedy this lack in the case of lignites by briquetting either before or

Fig. 132.—Carbocoal Plant of the International Coal Products Corp., Clinchfield, Va.

after the carbonizing process. Unquestionably, briquetting is equally applicable—if not more so—to the products of low temperature coal carbonization, providing a mechanical bond not possible by chemical or thermal methods. This statement should be modified to admit of the possibility of forming dense low temperature carbons by running the retorts under high pressure. Messrs. J. H. Capp and G. A. Hulett, in the *Journal of Industrial and Engineering Chemistry*, Oct. 1, 1917, report some experiments

along these lines. Four kinds of coal were heated in a steel retort at 611° C. at 300 pounds per square inch. The retort was heated in a tubular electric furnace to insure good temperature control. The capacity of the retort was nearly 2 liters. It was found that as the pressure increased, the yield of heavy hydrocarbons, of phenols and of acids decreased. The yield of light oils increased by 5 per cent. More and better coke was produced. The yield of gas was also increased. While it is evident that an excellent fuel can be produced by this method—provided the necessary conditions are met, it is also evident that the meeting of these conditions would involve large and unknown expense. On the other hand, the expenses incidental to briquetting are fairly well established.

Fig. 133.—Feed Mechanism—Primary Retorts. Carbocoal Plant. International Coal Products Corp., Clinchfield, Va.

Charles Howard Smith in 1915 began to manufacture carbocoal, a product resulting, in short, from the combination of both a low and high temperature carbonization and briquetting. The product is, in effect, a dense, dustless, clean, tough, odorless, free-burning smokeless fuel, uniform in size and quality. It has

a strong coherent structure, can be handled readily, and transported long distances without disintegration or loss from breakage. Heretofore, devolatilized fuels, such as coke, have failed to attain the high rates of combustion necessary for locomotive, marine and general steam purposes; and their greater displacement has operated against their general use where transportation cost or storage space has been an important factor.

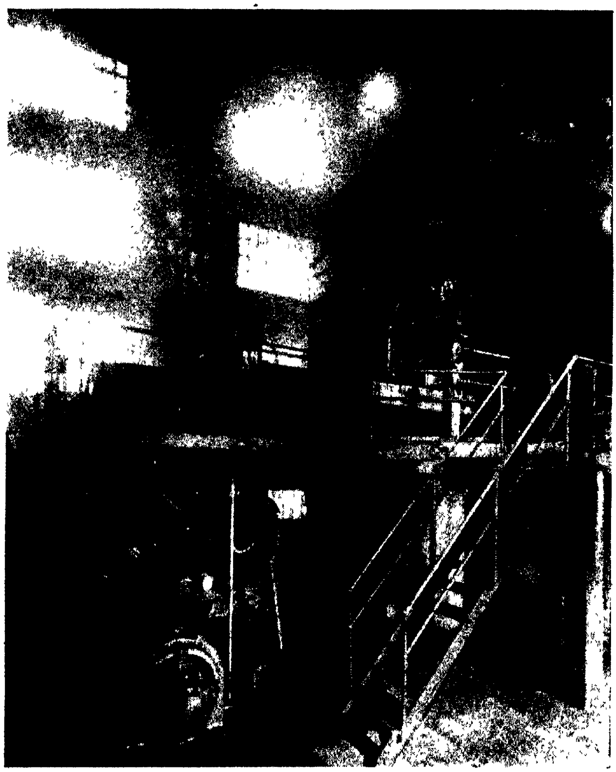

Fig. 134.—Interior of Briquette Plant. International Coal Products Corp., Clinchfield, Va.

Carbocoal claims to overcome these objections. Being readily attacked by oxygen in combustion, it requires much less draft than other high carbon fuels, thereby giving higher overall effi-

ciency. Carbocoal is manufactured in briquettte form ranging in sizes from 1 ounce to 5 ounces, the larger sizes being better suited to locomotive purposes, and the smaller sizes for domestic use.

In the Smith process, bituminous coal is crushed to about one-half inch and less and conveyed continuously through a cylindrical retort having a system of propelling paddles mounted on two shafts. The retort is lined with a refractory material. The speed of the paddle shaft is about one revolution per minute. The material is subjected to distillation for about 1 hour. The exterior retort lining is heated to 900° F. by the combustion of the gas evolved in the process through the medium of checker-

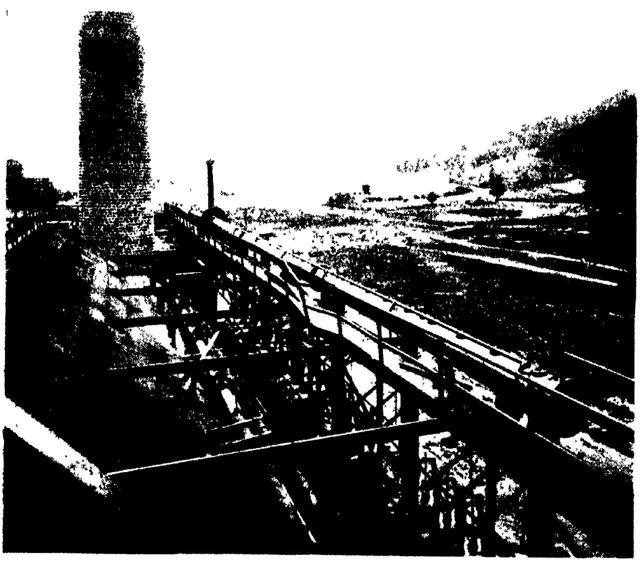

Fig. 135.—Top View of Secondary Retorts. International Coal Products Corp., Clinchfield, Va.

work preheaters installed below the fire box. The retort discharges into a hopper, where the semi-carbocoal cools. Thence it is discharged to a conveyor, which carries it to a Marcy ball mill crusher. The semi-carbocoal is there crushed to 20 mesh and less. The semi-carbocoal is mixed in a paddle mixer with 8 to 10

per cent of coal tar pitch, and the mix digested in a direct steam-heated vertical fluxer. The hot flux is fed into a briquetting press of the Komarek type (Chapter II) averaging two hundred and fifty briquettes to the revolution. The conveyor carries the briquettes to a hopper above the inclined retort feed doors. The secondary retorts at Clinchfield consists of two batteries of 35° inclined ovens—six in one battery and four in another with three carbonizing tiers to each oven. The inclined retort has proved most satisfactory. The finished briquettes discharge by gravity to a coke carriage in which they are quenched. The degree of carbonization in the inclined retorts can be controlled so that any predetermined amount of volatile matter is retained. At the present time only 3 per cent is left—enough to ensure free burning quality.

In the low temperature carbonization of the coal, the evolution of the gases is strongest at the discharge end. An additional outlet is connected with the gas main in conjunction with a central connection. The water seal is placed at a lower level than in gas making so that less back pressure in the retort is obtained. The gases are cleaned as in ordinary gas practice. Table XVI indicates the main divisions of the products and their amounts.

TABLE XVI.—PRODUCTS OF THE CARBOCOAL PROCESS.

Coal 2000 lbs.	Carbocoal briquettes, 1440 lbs.			
	Gases and vapors, 560 lbs	Vapors, 360 lbs.	Tar oils 250 lbs.	Benzol, toluol, naphthas, motor spirits, creosote oils, tar acids, lubricating and fuel oil, pitch and other tar products
			Ammonia 20 lbs.	Ammonia (concentrated), sulphate of ammonia, cyanogen, pyridine bases, and other nitrogen compounds
		Permanent gases required in the distillation process for heat 200 lbs.		

The tar obtained in the primary distillation has a specific gravity of 1 to 1.06. This tar contains no naphthalene, anthracene or carbolic acid, but is rich in oils, tar acids and cresols. The light condensates are passed through long tubes at high temperature, giving a large yield of pure aromatics. Table XVI gives the tar products produced per ton of coal.

TABLE XVII.—RECOVERY OF LIQUID PRODUCTS PER TON OF RAW COAL.

	Dist. temp. Deg. F.	By-product coke oven Gal.	Per cent	Carbocoal First dist. Gal.	Per cent	Carbocoal Sec. dist. Gal.	Per cent
Light oil	0–170	0.27	3.47	1.58	6.60	0.003	0.05
Middle oil	170–230	0.44	5.85	3.29	13.70	0.036	0.60
Creosote oil	230–270	0.78	10.37	3.11	12.95	0.126	2.10
Heavy oil	270–360	1.26	16.81	8.88	37.00	2.485	41.42
Pitch		4.66	62.18	6.90	28.75	3.290	54.83
Loss		0.09	1.32	0.24	1.00	0.060	1.00
Totals		7.50	100.00	24.00	100.00	6.000	100.00

The increase of the products in this process over by-product coke oven practice is mainly in the oils, the factors being: light oil, 6; middle oil, 8; creosote oil, 4; heavy oil, 9; and pitch, 2. These oils can, in part, probably be used as solvents and motor fuel. The pitch is low in free carbon.

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CHAPTER XIII.

THE DEVELOPMENT OF FLUE DUST BRIQUETTING.

It is well known that the iron ore supply to-day contains a far greater percentage of fines than that of two decades ago. Further, the proportion of fines to lump is constantly increasing, due to the continued gain in production of Mesabi ores. The use of high pressure blast and heavier burden—the blast furnace practice of late years—has tended to accentuate rather than relieve the condition. The production of troublesome flue dust has, therefore, been increased for more reasons than one, and the recovery of the iron in this dust has formed the subject matter for long investigation, both here and abroad.

The return of the dust to the furnace, as such, has not met with general favor. It is to-day the consensus of opinion that the dust should be agglomerated before return to the smelting operation, either by sintering or by briquetting.

Fine ferrous material from the blast furnace is now commonly divided under three heads:

Dry dust—which is the usual by-product of blast furnace production—the material commonly associated with the term "Blast Furnace Flue Dust." It is collected in the dust chambers of blast furnace plants.

Wet dust—the very fine mud which is the product of the various wet methods of gas cleaning. The cleaning has been necessitated by stoves, gas engine and other combustion requirements.

Filter dust—the product of dry cleaning of blast furnace flue gas, as by the Kling Weidlein method, after the coarser dust is removed. It has the consistency of flour.

It is of primary importance that any method adapted for the treatment of flue and filter dust from a modern blast furnace should be *efficient* in its treatment of *each* of the three above mentioned.

The second requirement, and of hardly less importance, is *simplicity*. There is little room in blast furnace operation for complicated mechanism; and the third requirement, that of *low cost,* is self-evident.

Certain processes of sintering have met with favor in the United States. Briefly, sintering is a reducing process, wherein the iron

bearing material is intimately mixed with the amount of carbon required. The carbon is the contained coke, provided the coke be present in sufficient quantity. The mixture is moistened, set in a uniform layer, surface ignited, and submitted to a current of air. By the combustion of the carbon and the resultant heat, the

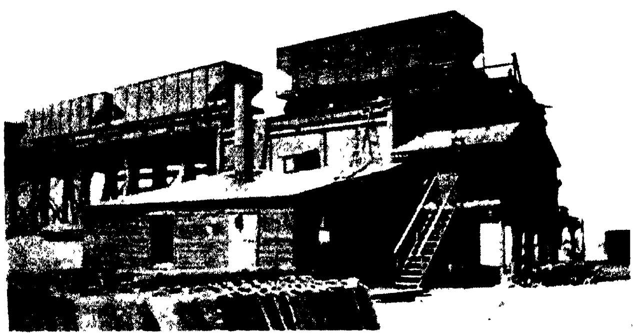

Fig. 136.—Wickwire Steel Co. Briquetting Plant, Buffalo, N. Y. Showing Delivery of Flue Dust to Briquetting Plant.

iron-bearing material is agglomerated into a more or less coherent mass. Sintering is claimed to increase reducibility, but the claim is debatable. Several plants have been installed.

In general, the methods of flue dust preparation for recharging to the blast furnace may be classified as follows:

TABLE XVII.

By sintering	By briquetting and sintering	By briquetting only		
		By pressure only	Binder methods	Chemical methods
Dwight and Lloyd, Greenawalt, Plock, Dreyman, West Briquetting not involved	Gröndal method	Ronay method	Trainer method (with zellpech) Briquetting with various binders—pitch, bitumen	Mathesius methods (Scoria process) Schumacher methods (catalytic method) The modern "Corrosion" process

It is not the province of this work to describe or discuss the various methods of sintering. This does not imply that they do not have a high value; it merely means that in their operation—with the exception of the Gröndal process—briquetting is not involved.

Gröndal Method.—The Gröndal process has been applied, primarily, to iron ores. It has been used—and especially at the Edgar Thompson Works of the U. S. Steel Corporation—for treating flue dust. There is no question but that the product obtained is highly satisfactory from the technical point of view. The cost, however, is higher than the processes in which briquetting only is involved.

The flue dust must be dampened to maintain its brick form after pressing. The proper percentage of moisture varies with the hygroscopic qualities of the mix. The man at the press soon learns the right moisture content. Drop presses of the Dorstener type modified by Dr. Gröndal, are used (Chapter II). The standard size of the briquettes is 6 x 6 x 2.5 inches. Each car is loaded in two tiers so that the load stands 12 inches high. Care is taken to place them so that later the furnace gases can penetrate the load and heat the rows thoroughly. The press man removes the briquettes from the press and places them on the car—30 tons in a 12-hour shift. The press delivers from 12 to 16 briquettes a minute. The loaded cars are pushed through a Gröndal furnace at intervals, one car being admitted at a time.

The Gröndal furnace is a channel, heated by means of gas introduced through the raised arch at a distance from the entrance-end of about two-thirds of the furnace-length. The flat cars are usually built of structural steel with fire-brick tops, furnished with flanges dipping into sand troughs. The furnace walls are built double, with an outside wall of red brick and an inside one of fire-brick; the two being separated by an air space. In the first third of the furnace the briquettes are heated by the combustion gases and they pass through zones of increasing heat. In the combustion chamber the heat is maintained at about 2,500° F. After passing the combustion chamber, the briquettes go through the cooling chamber, into which air is blown. When they leave the furnace, they are cool enough for loading. The movement of cars through the furnaces is obtained through the use of

a hydraulic ram or some similar contrivance, which requires little power. The discharged car is unloaded by a plow or by tipping. The frequency with which the cars are charged depends upon the nature of the ore. High sulphur ores have to be charged at a slower rate.

The latest design of furnace for use in the Gröndal process is the Ramen "kanal oefen" described in "Erzgebau" 1912 No. 14. See Chapter XIV.

Ronay Method.—The operation of the Ronay process is extremely simple. In the general arrangement of the Ronay briquetting installation, the dust ore or flue dust arrives at a storage bin and is lifted by elevator to a screen, and, after passing through the screen, whereby all the larger pieces are eliminated, it drops into a bin. The screened material is carried by belt conveyor to a small hopper, from which it passes into the press. The finished briquettes are taken from the press by belt conveyor and loaded into small cars, which run to the blast furnace.

The labor needed consists of a machinist, a man at each press, and two men at each belt conveyor to discharge the briquettes. The capacity of each press is, according to the weight of the dust ore or flue dust, from 5 to 8 tons per hour.

The flue dust, moistened to a proper degree, is introduced into the Ronay press (described in Chapter II). No binding material is added, so that no mixing or grinding devices are needed. It is said that the high pressure serves to help oxidation, thereby building up cementing action. The pressures used are high—about 25,000 pounds per square inch. This process has never been used in the United States for flue dust briquetting, although it has been popular, as hereinbefore mentioned (Chapter III) in reclaiming metal swarf. In Germany, the following plants have been installed: Oberschlesische Eisenbahnbedarfs Aktiengesellschaft, Friedenshuette, Upper Silesia; Lothringer Huettenverein Aumetz-Friede in Kneuttingen, Lorraine, and Gutehoffnungshuette in Oberhausen.

Trainer Method.—Professor Trainer developed the method of using the cellulose liquor waste as a binding material for blast furnace flue dust in certain instances. The outstanding

example of this method is the plant of the Gewerkschaft Pionier of Walsum on the Rhine, Germany, from whence the process is sometimes colloquially known as the "Pionier" method.

The liquor is mixed hot in a steam-heated mixing device with the flue dust and is pressed in toggle presses (the plant has two) under fairly high pressure: 6,500 pounds per square inch. Latterly, it has been the practice at this works to add the aqueous solution to the flue dust while hot, obtaining thereby an evaporation of the greater part of the water, and obviating the necessity of an evaporator plant for the cellulose liquor. It requires a fairly high degree of skill to maintain a proper moisture content prior to the pressing operation. It should be said, however, that the briquettes resulting are excellent when properly taken care of. So far, this process has not been adopted in the United States., nor, indeed, has it spread to any great degree in Europe. It is necessary that cellulose liquor be near at hand in quantity and at low price for commercial success for this operation.

Due to the limitations of coal briquetting binders as applied to the blast furnace (outlined in Chapter VI) there have been no great installations either of ore or flue dust briquetting where such binders have been used. None the less, such practice has been recommended by certain German authorities and very extensive research and tests have been run thereon.

Crusius Method.—George Crusius, of Gross-Ilsede, Germany, advocates the briquetting of ores and flue dust by mixing with coal tar, which has been deprived of its water, its light and middle oils, retaining its heavy oils; and thereafter subjecting the mixture to pressure in a reciprocating press. An investigation in the costs of the various methods of flue dust briquetting, presented by Ernest Stuetz in the *A. I. M. E.*, Vol. 47, shows that the Crusius process required 4 per cent of prepared tar added to a mixture of fine ore and flue dust, and the cost is one of the lowest of flue dust utilizing processes. Despite this fact, there is no evidence that the process has any vogue in Germany to-day.

Dunkelberg Method.—Dr. F. W. Dunkelberg of Wiesbaden has advocated a method of briquetting whereby inorganic and organic binders are mixed prior to the briquetting operation. This binder consists of infusorial earth, carnalite and molasses leas (refer. *Stahl und Eisen,* 1909, pp. 551-552).

Rudolphs and Landin, Huffelmann and Wedding Methods.—Messrs. J. Rudolphs and J. Landin have taken out a German patent whereby ores and flue dust are mixed with coal and tar for the purpose of making briquettes, and W. Huffelmann of Duisberg has protected a process for mixing fine iron ore or flue dust or both with coke fines and lignite together with coal tar pitch. The Patent of Dr. H. Wedding calls for the mixture of flue dust with asphalt or petroleum residuum.

Of the various inorganic binders, the only ones to be taken seriously in this connection are lime or lime and silica, forming a calcium silicate cement. There is veritably a myriad of different processes involving silicate of calcium as the binding agent in ore and flue dust briquetting, either intermixing the silicate as such or manufacturing it in the course of the mixing and briquetting operation.

Schumacher Methods.—Probably the first to put into practice an economical method for briquetting with calcium silicate was Dr. Wilhelm Schumacher of Osnabrueck, who patented in 1907 a process for the production of coherent bodies from fine ores, blast-furnace dust and the like, consisting in subjecting a mixture of finely divided calcium silicate with the substance to be agglomerated, to the action of steam under pressure. The amount of calcium silicate used was less than 5 per cent. Later, Dr. Schumacher adopted the method of mixing pulverized silica and lime, and adding this mixture to the substance (ores and flue dust) to be briquetted and subjecting the mixture to the action of steam as before. Under the action of the steam the silica and the lime formed calcium silicate, and a very hard briquette was the result. Later, Dr. Schumacher abandoned these methods for the famous Catalytic Process hereinafter described.

Kippe Method.—In this connection, the use of filter dust for the briquetting of blast-furnace flue dust as advocated by Dr. Kippe and outlined in Chapter VI, is worthy of note.

Mathesius Methods.—Meanwhile, Walther Mathesius and Oberschultte, working along similar lines, evolved the *Scoria Process* whereby a calcium silicate binder was added to the mixing of ground slag and lime.

Prior to the Great War, the Scoria process had been in active operation at the Rheinhausen works of Friedrich Krupp A. G., working at a capacity of 400 tons per day. This method uses slag

—(called in Germany scoria)—as binder for flue dust. For this binder is claimed the merit of being hydraulic until it passes into the furnace where it is transformed into a fusion binder. The metallic oxides are free to react during their passage. The binder gives the briquettes the necessary strength to support the weight of the stock pile. In preparing the briquette mix, granulated slag and lime are mixed with the fine dust and made hydraulic in rotating steaming drums, where the mixing materials are exposed to low pressure steam. When thoroughly mixed, ground and screened, the mass is conveyed to the presses

Fig. 137.—Flue Dust Briquettes in Storage. Wickwire Steel Co., Buffalo, N. Y.

and formed into briquettes. The briquettes are carried in trains to cylindrical kilns, in which they are hardened by being exposed to the action of high-tension steam for from 8 to 10 hours. The hardened briquettes go from the kiln to the blast-furnace bins.

The further work of Mathesius in improving the Scoria process has been described in Chapter VI. It is interesting in this connection to record that the Humboldt Company installed an eggette press (Belgian type) in connection with the Mathesius' patents for the briquetting of flue dust. It is recorded further, however, that the eggette press was rejected because the briquette was not

sufficiently hard when it left the press, but requires a steam-hardening process thereafter, and the briquette was not sufficiently strong to stand the handling prior to the hardening.

Other systems that have been tried in the manufacture of flue dust briquettes with inorganic binders are the Dahl (8 per cent lime, 1 per cent slag); the German Briquetting Gesellsch. (10 per cent lime and cement); and others involving the use of water glass and gypsum; none of which, however, show any great promise for the future.

Fig. 138.—Briquettes in the Blast Furnace Charge. Wickwire Steel Co., Buffalo, N. Y.

Lammerhirt Method.—At the "Phoenix" Dortmund plant a very unique method of briquetting the various iron wastes has been adopted. Flue dust, roll scale are mixed with the iron oxide waste of the aniline factories together with iron filings. This mixture, under fairly heavy pressure, gives excellent briquettes without the addition of binder. Undoubtedly, an oxidation occurs and the iron oxide forms the binding cement. Such a method has been patented in the United States in the name of J. R. H. A. Laummerhirt.

Schumacher Catalytic Method.—The greatest single advance in the research for methods of flue dust utilization came in 1909 when Wilhelm Schumacher perfected the *Catalytic Method* of briquetting. Schumacher discovered that blast furnace flue dust contained binding ingredients, which could be rendered very active by a catalytic reaction. By the addition of certain salts— espe-

cially chlorides, (except those of the alkalis)—sulphates and sulphites—more particularly those of the earth metals—this binding medium was rendered active, and with the evolution of heat under pressure, the blast-furnace flue dust hardened like cement within a few hours. "It will be well understood," says Dr. Schumacher, "that these salts do not themselves form any compounds, which act as binders for the mixture in any material degree, but their action is chiefly catalytic; that is, they determine and stimulate the binding action of the materials contained in the blast-furnace dust." In connection with the Schu-

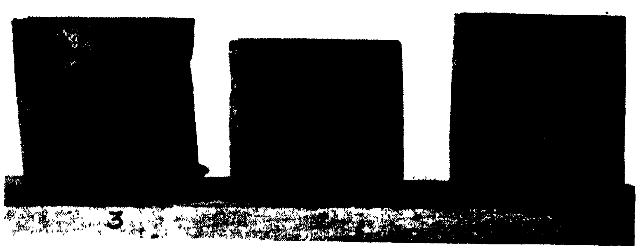

Fig. 139.—Characteristic Fractures in Flue Dust Briquettes Broken Under Test at Cambria Steel Co. Laboratory. (Though Made on the Ronay Press, these Briquettes Were Made by the Schumacher Process).

macher process, lime and cement or other compounds of strongly alkaline character, should never be used. The following are the installations in Germany of the Schumacher process: Konigshuette in Upper Silesia; Rombacher Huettenwerke, Rombach; Eisenhuetten Aktienverein Dudelingen, Dudelingen, Luxemburg; Dortmunder Union in Dortmund; and Hasper Eisen and Stahlwerke at Haspe, Westphalia. There is also an installation at the Cockerill Works in Belgium.

At the German plants the catalytic salt usually used is magnesium chloride.

In the United States the Schumacher process has been adopted and an installation made at the Wickwire Steel Company, Buffalo, N. Y.

The dust is loaded in cars at the furnaces and stock pile and carried on a trestle over the plant. The cars dump the dust on a grizzly where the lump coke is removed. The dust passing

through the grizzly goes to the feed bin, and is fed thence to the mixing table. Here 10 per cent solution of catalytic solution, containing one-half of 1 per cent of the salt (dry) is added. Thorough mixing of the dust and catalytic solution is obtained in the succeeding operation, kneading in a horizontal trough paddle mixer. Here the chemical action begins. From the paddle mixer the mixture goes to a vertical feed hopper, then to a Schumacher press (described in Chapter II). The chemical action of the process is well under way as the briquettes are molded in the press, the next step in the operation. From the press, the green briquettes are carried on a traveling belt to a storage room, where they are seasoned for 24 hours, when they are in condition for smelting.

Fig. 140.—Schumacher Press and Process Making Flue Dust Briquettes at the Plant of the Wickwire Steel Co., Buffalo, N. Y.

At the Wickwire plant briquettes, when used, form 10-15 per cent of the furnace charge.

There have been other installations of the Schumacher process in the United States, notably at the Lackawanna and Cambria Steel Companies. The large size of briquette produced by the Schumacher press used and the consequent amount of handling necessary—and that, too, by hand—acted unfavorably upon the process at those installations.

Another installation—that at the Buffalo Slag Company, supplying briquettes to the Buffalo Union Furnaces of the M. A. Hanna Furnace Co.—found the briquettes an excellent furnace

feed, but interposed objections on similar grounds after the installation of the plant. The process was modified at the latter installation to what has been designated the *"Corrosion" Process.*

A large Schumacher press at the Buffalo Slag Company plant was discarded and in its place was substituted a "Universal" press (as described in Chapter II). The peculiar advantage of this press in respect to flue dust briquetting lay in the fact that the rolls were self-feeding and pressures on the briquettes were ad-

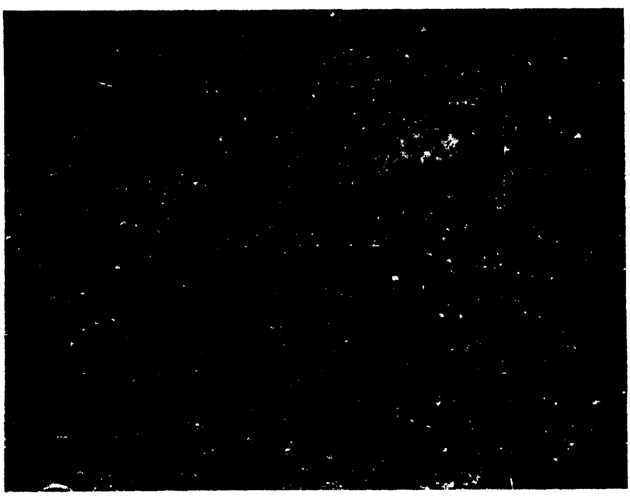

Fig. 141.—Microphotograph of Briquette of Blast Furnace Flue Dust (mag. 20 diameters).
a—Limestone Grains—Light Gray.
b—Coke Grains—Dark Gray.
c—Fine Grained Flue Dust.

justable to high maxima. It was, therefore, possible to generate a sufficient pressure upon a flue-dust briquette to render it sufficiently strong to stand the short drop from the press roll to the chute, which must occur before the seasoning set had begun.

When the Buffalo Slag Company's plant was installed, it was anticipated that, sooner or later, the call to treat wet dust in conjunction with the dry would come. This anticipation led to certain modifications of design.

The dust is delivered in cars and screened as at the Wickwire plant. The present layout of the Buffalo Slag Company plant is as follows: There are two feed bins, each adapted to deliver a measured quantity of material. One of these was to receive the wet dust, which has not as yet appeared. The feeding tables are in duplicate, one for each bin, and discharge into the horizontal trough paddle mixer as at Wickwire, wherein 10 per cent acid solution (ferrous sulphate—½ per cent on dry basis) is added

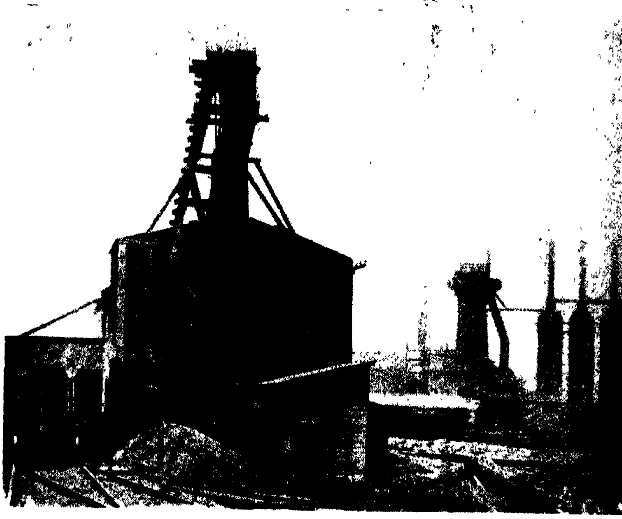

Fig. 142.—Flue Dust Briquetting Plant of the Buffalo Slag Co., Buffalo, N. Y.

and thoroughly admixed. The mixing can be so arranged that the moisture in the wet dust (when it does appear) will replace a large part of the water of the solution. The solution would then be added in concentrated instead of dilute form. In this event more intimate digestion of the dust with the solution was deemed desirable. Hence, a notable modification in design occurs.

The mixed flux of dust and solution is fed from the paddle mixer into the pan of a masticator (see Chapter X). The mastication, and by that is meant the digestion of the flue dust with its admixture, has proven of utmost importance. Although the masticator was originally installed with the idea of treating

wet pulp from the gas washers in conjunction with the dry dust, the event proved a highly increased efficiency of binding power obtained when (as the continued practice of the Buffalo plant came to be) only dry dust was treated. The flue dust at all times

Fig. 143.—Plant of Buffalo Slag Co., Buffalo, N. Y. Universal Press Making Flue Dust Briquettes.

has a high latent setting power, which the addition of the solution develops. So high is this bond under normal conditions that an excellent briquette can be made, using thirty parts of flue dust and seventy parts inert material—fine hematite ore for instance (which

possesses no latent cementing power). A large proportion of finely divided coke is, invariably, contained in flue dust and is incorporated into the briquettes, subsequently realizing to the full its reducing value in the blast furnace. Certainly, briquetting is the only avenue of utilization for this fine coke. It has been found that the mastication increases perceptibly this carrying ability of the flue dust, and permits a greater degree of admixture of inert material. Then, too, by mastication the combined breaking of the dust particles together with the better diffusion of the solution produce a more rapid and efficient chemical action.

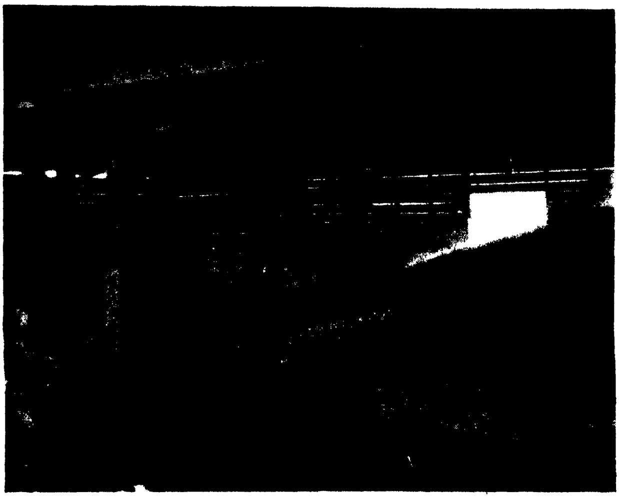

Fig. 144.—The *Old* and the *New* in Flue Dust Briquetting. Pile to Left—Brick-Shaped Flue Dust Briquettes Made on Schumacher Press. On Belt Rear—5 ounce Pillow Shaped Briquettes Made on Zwoyer-Universal Press. Note Steaming Caused by Chemical Action.

The use of the masticator on flue dust, especially the incorporation of wet pulp from the gas cleaners with the dry dust, is covered by U. S. patent 1,312,218, August 5, 1919, issued to Felix A. Vogel.

From the masticator the flux, thoroughly digested, is conveyed to the press. The molds of the press at the Buffalo Slag Company's plant turn out pillow-shaped 5-ounce briquettes in place

of the old brick-shaped briquettes. They travel along a belt and consume one hour in reaching the storage or the cars. During this hour a very excellent initial set is reached.

The chemistry of the process involves the breaking up of the ferrous sulphate, forming a ferrous hydroxide and sulphuric acid. In the presence of oxygen the ferrous hydroxide becomes ferric, and the sulphuric acid formed attacks the ferrous oxide of the flue dust forming a ferrous sulphate anew, which continues the cycle. The action is exo-thermic, and a large quantity of heat is evolved. (See Chapter VI).

In the subsequent drying the ferric hydroxide sets in a horn-like substance. At this point it is probably the normal hematite, or Fe_2O_3. Assisted by pressure and subsequent drying an extremely hard and durable briquette is formed.

Advantages of Briquetting Flue Dust.—All blast furnace men recognize the advantage of agglomerating their fine materials for, whatever the method, such agglomeration increases the regularity of furnace operation; increases the metal produced; decreases the coke consumption and dust production, and through the combination of these factors lessens the cost of producing pig iron. To achieve the proper agglomeration, briquetting of blast furnace flue dust has the following claims:

1. The briquetting plant is the lowest in first cost of all known processes of agglomeration.

2. The briquettes cost less per ton to produce than any other agglomerate.

3. Briquettes give maximum yield from the coke and flux of the flue dust. As they are returned to the blast furnace in their original form, all their reducing value and contained heat do useful work.

4. Briquettes have 25 per cent porosity, allowing the proper heat transfer.

5. Briquettes have no silicates nor glazed surfaces. The iron is in the most easily reducible form.

6. Briquettes are strong. Professor Richards found a minimum of 445 pounds per square inch compression resistance in his tests on the large Schumacher briquette. The Universal press briquette is stronger. Properly seasoned, they stand hand-

ling well. They hold together in the furnace. Briquettes placed their shape, and when withdrawn proved to be sponge sinter. (See frontespiece).

7. Combined with preliminary mastication, briquetting forms the only solution to the problem of returning wet pulp from the gas cleaners to the blast furnace. The wet pulp masticated with dry flue dust makes excellent briquettes.

8. Combined with preliminary mastication, briquetting is the answer to the problem of treatment of the dust produced by dry gas cleaning as from the Kling-Weidlein filters. It has heretofore been extremely difficult to "wet down" this dust as it is so fine that water will not of its own weight penetrate the mass. The mastication forces the penetration of sulphate solution, and the resulting cementation is excellent. The finer the pulp, the better the merit of the mastication.

9. Briquetting fine ore with flue dust is an excellent method of preventing the formation of too great a burden of fine dust.

10. Briquetting is the simplest method of disposing of flue dust. It requires no fires, no heating, no highly skilled labor, no close technical supervision.

11. Intermittent operation of the briquetting plant is practicable without additional expense.

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D. R. P.	No. 298,736 to Phoenix Akt.-Ges. Fuer Bergbau U. Huettenbetrieb—Aug. 3, 1916.
U. S. P.	No. 1,312,218 to Felix A. Vogel—Aug. 5, 1919.
U. S. P.	No. 1,315,315 to J. Lammerhirt—Sept. 9, 1919.

CHAPTER XIV.

THE BRIQUETTING OF ORES.

Practically all briquetting methods, and indeed practically all brick-making methods, have from time to time, been tried out in the agglomeration of ores for metallurgical purposes. Most of the toggle and tangential presses described in Chapter II have been used in various installations in such preparation. The vast majority of the instances of ore briquetting have occurred as an incident to preparation for the blast furnace.

A classification of the various objects of ore briquetting is as follows:

I.—Briquettes made from ores to facilitate blast furnace operation.

II.—Briquettes made from ores to facilitate distillation in retorts.

III.—Briquettes made from ores to act as resistors in electrolytic smelting.

In addition, iron ore is often used in the open-hearth furnace for the purpose of decarbonizing and enrichment. Such ore must be rich in iron, and free from substances that might hurt the quality of the steel produced. Magnetic ore concentrates and briquettes made therefrom fulfil these conditions. The sulphur is well below required limits. When iron ore is so used 21 per cent is the maximum addition. Briquettes made from such concentrates need not be heated to more than 1,400°; nor is it necessary to oxidize them from Fe_3O_4 to Fe_2O_3; nor need they be porous. They can be formed by high pressure methods, whereby they become exceedingly compact, a condition advantageous for use in the open-hearth furnace, as they sink deeper in the bath, and do not float upon the surface, as does red or brown iron ore.

I. The Briquetting of Ores for the Blast Furnace.—The importance of reducing the proportion of fine materials in the blast furnace, especially as applied to iron, has been outlined in the preceding chapter. The blast furnace is used in the smelting of many metals and is especially important in the reduction of iron, copper, and lead. In these widely divergent metallurgical fields, involving the smelting of oxides, sul-

phides, carbonates, and other mixtures with the accompanying features of roasting, pre-roasting, and at times pyritic smelting, briquetting has performed its part. Although the metallurgy of the copper and lead ores is basically more complex than that of iron, in that longer processing is required to obtain metal, the briquetting of such ores and residues never reached the high technique that has been attained in iron ore briquettes. Due to far lower tonnages, peculiar local conditions, in nearly every instance, and the natural desire of each smelting superintendent to solve his own problems, there has, with the single exception of the Chisholm, Boyd and White method, until recently, been no standard method of briquetting such ore. Again, many of these ores were rich in clay, and, especially in districts where labor is cheap, the most primitive methods of hand molding sufficed, or, failing that, clay brick-making. This making of mud cakes is extremely crude—moisture sometimes up to 40 per cent has to be evaporated during the smelting process and the briquettes are not especially strong. Instances are found in Japan, especially in their copper metallurgy; however, these methods are largely falling into disuse and the practice has been much improved.

A typical instance of briquetting applied to copper smelting is described by Manuel Eissler in "Copper Smelting in Japan"—*Trans. A. I. M. E.*, Volume 51. A typical installation is the plant located at the Kano mine. The ore at this mine is extremely complex—the mineral consisting of iron and copper sulphides, zinc blende, and barite, with galena carrying silver. The gangue is clay carrying a large proportion of aluminum. One hundred and fifty tons of ore are mined daily, of which 40 tons are lump and go direct to the furnace; the concentrate from the balance (about 45 tons) is mixed with clay ores in pug mills. From the pug mill the ore is fed into portable molds by the operators, and placed by hand under large wooden stamps. The operator places the filled mold beneath the stamp, releases the stamp, which descends on the mold, forming the briquette; the stamp is raised, the mold withdrawn and the briquette knocked from the mold and loaded on a tray. The stamps work in batteries—twenty-four molding stamps in all. The briquettes are taken on their shelves to drying furnaces, each with a capacity of 40 tons. The flame passes over the first shelf, up a flue and back over the

second, through another flue and over the third shelf. The furnaces require two shifts of fourteen men working 12 hours. In addition to the materials already mentioned, roasted pyrite from sulphuric acid works is bought as a fluxing material and the fines are added to the briquettes. In this case a very simple method of briquetting has helped solve a very vexing problem in pyritic smelting. Similar methods of briquetting are employed at the Kosaka mine, but the briquettes form a much smaller portion of the charge.

At the Ashio Works of the Furikawa Mining Company, one-half the charge, consisting of fine concentrates and a small proportion of cement copper is briquetted. An interesting method of treatment is noted: The fine concentrates, briquetted, are placed, while damp, in a series of cast iron pots mounted on an endless chain. The line of pots is passed under a stream of matte prior to smelting.

At the great Ikuno smelter the concentrates are made into briquettes after being mixed with 5 per cent milk of lime. About thirty women are employed in the briquette making, each molding about 800 per day. This work is done by hand. The briquettes are cylinders, 4 inches in diameter and 5 inches high. They are dried by flue gases in chambers holding 30,000 briquettes. Drying requires a day and one-half. At this plant both raw and roasted ores are briquetted.

Advantage is taken of the clay in the native ores in the works at Kertsch, Russia, and Ilsede, Germany. At these plants from 6 to 8 per cent of water is added to the ore and the briquettes are formed in plunger presses at about 4,000 pounds per square inch. Drying is done at a temperature of 75° C.

An interesting application of brick-yard methods to the briquetting of copper ores is described in the *British Columbia Mining Record* of July, 1905, in connection with a visit to the Tyee smelter. The location of the Tyee smelter is Mt. Sicker—51 miles from Vancouver in British Columbia. The description of this operation is as follows: The ore is brought in 30-ton railway cars. The ore to be smelted raw goes to bins behind the furnace, and that to be roasted to the bins at the highest level in the yard. The ore is screened and the fine ore (three-eighth -inch size and less) falls into a separate compartment. From the

bins the ore is discharged into cars, the large sizes going to the roast and the fines to be made into bricks. The bricks of fines are roasted with the ores. The process of making the fines into bricks is that of ordinary brick-making. The plant consists of two 1 horsepower pug mills and a bottom-heated drying floor. The capacity of this plant is 8,000 bricks, or 28 tons of ore per day. After burning, the bricks are hard and porous, and suitable for smelting in the blast furnace. The oxidation of zinc, copper and iron in the bricks is thorough. Average samples of burnt bricks give from 1.5 to 2.5 per cent of sulphur. The ordinary burnt ore shows 7 per cent. This process, peculiar to the locality, obviates the need of mechanical roasting furnaces. The bricks stand handling and rough usage and are a valuable addition to the furnace-charge.

In Germany a hydraulic press designed by Brueck and Huebner (but whose description is withheld) Mannheim, is used at the Koenigshuette O. S. for briquetting cement-copper. The latter is reclaimed from the copper extraction plant after the exhausted pyrites has been cleared of the lye by precipitation. The copper briquettes have the shape of small bricks, and are sold.

At Mansfeld, Germany, lead flue dust, collected from the Mansfeld Cupriferous Slate Smelting Works, is pressed into bricks, which after baking are delivered to the Eckhardt Raw Smelting Works. Here they are smelted in a shaft-furnace provided with a gutter arrangement for feeding coke and grate cinders having a high iron content, with limestone and iron oxide, lead containing silver, and nickel speiss.

At the Anhalt Silver Smelting Works (in the south Harz), all flue dust (with about 50 per cent lead content, a small quantity of copper and a small percentage of antimony), is mixed with purple ore derived from calcined pyrites and with burnt lime, and formed into hand bricks in such proportions that through the melting of these bricks a free liquid slag is formed, which contains 28 per cent SiO_2, 35 per cent FeO and 16 per cent CaO; that is, if no zinc be present; in case it is present the admixture of lime is limited to that required to obtain a slag containing 10 per cent lime.

In the iron industry the most notable ore containing clay in such quantities as to seem available for briquetting binder is in

the Mayari ore of Cuba. Very earnest efforts have been made to briquette this ore. The Mashek briquetting press and system have been applied to the treatment of raw Mayari ore. The press roll was modified so that the corrugations ran parallel to the axis of the rolls on the surface. Cylinders of compressed ore approximately 12 inches long and 1½ inches in diameter were made. These briquettes could not stand weathering well, and should be charged immediately into the furnace. However, the cost of mining of Mayari ore is exceedingly low, and a means by which the ore may be successfully prepared for use in its natural state is sure to prove attractive. Diffiiculty was experienced in obtaining a good discharge of briquettes from the press. The various disabilities of the briquettes formed led to the abandoning of the experiments and to-day the Mayari ore is treated in nodulizing kilns. Mr. G. J. Mashek, who designed the press, is primarily a coal briquetting engineer, and, while at all times interested in the briquetting of other fine materials, has never felt that a very large future lay before the briquetting of ores and concentrates; as is shown from the following quotation from the Mashek Engineering Company's catalog: "We do not recommend the briquetting of ores, concentrates, flue dust, etc., where any of the other well-known methods would accomplish the desired results, such as reverberatory furnaces and different sintering methods that have been developed. Practically all ores can be readily briquetted. It is usually necessary to crush them fairly fine, and where sodium silicate is not objectionable, it makes an excellent binder. A small percentage of sulphite pitch will combine most ores for all practical purposes. Lime alone or mixed with a small amount of Portland cement makes a satisfactory binder for many ores. Many ores of the plastic or sticky nature, or having cementing qualities, can be briquetted without the use of binder. Where the above mentioned binders are used, and it is desired to store or ship the briquettes, it is necessary to pass them through a drying oven to expel the moisture and harden the briquette the same as in the use of binders on coal. Coal-tar pitch, asphaltum and heavy mineral oil, can also be used, which may not require the use of a-baking or drying oven, but as a rule are too expensive, and often objectionable for this purpose."

Notwithstanding the fact that Mayari ore is one of the most difficult problems from the briquetting point of view, it may safely be predicted that a briquetting operation will form a part of the future processing of Mayari ore.

In the Western United States there has been a series of installations of Boyd brick presses and White briquetting presses (see Chapter II) in the smelting practice of copper, lead, silver, and other ores. Brick presses were used at first, but latterly the White press became more popular for the purpose. At least fifty installations were made. Most of the ores concerned had a silica gangue, were deficient in clay, and required lime or organic binder. The use of lime was quite usual. The layout of a typical plant is shown in Figure 145. The ore or concentrate is delivered to an ore feeder with measuring device by conveyors or elevators. The lump lime is fed into a mechanical lime slacker and thoroughly digested, after which it is pumped in proper proportion into a paddle mixer. The automatic feeder discharges the fines in measured quantities into the same mixer, and the binder and ore are thoroughly mixed, as in coal briquetting. The mixing blades of the conveyor mixer are set at an angle to convey the material to the discharge end, whence it is dropped to a White press. The percentage of bond used is regulated by an adjustment of the pump, and the fine ores, flue dust, etc., may be delivered to the automatic ore feeder and mixer at one time. From the press the briquettes pass on a conveyor belt, which is in continuous operation. The delivery end of this belt has an adjustable arm which automatically loads the finished briquettes into receptacles which can take them direct to the furnaces, or to bins, as required.

At the Copper Queen Mine in Arizona, the practice has been to briquette one-tenth of the blast furnace charge by the above process. The briquettes were a mixture of fine ore, flue dust, and coke braize.

At the Val Verde Copper Company at Val Verde, Arizona, copper ores containing arsenic, antimony, lead and zinc were successfully smelted without preliminary roasting in an ordinary blast furnace with hot blast, producing marketable matte free from arsenic and antimony and below the penalty limit in lead and zinc. The smelting mixture was as follows:

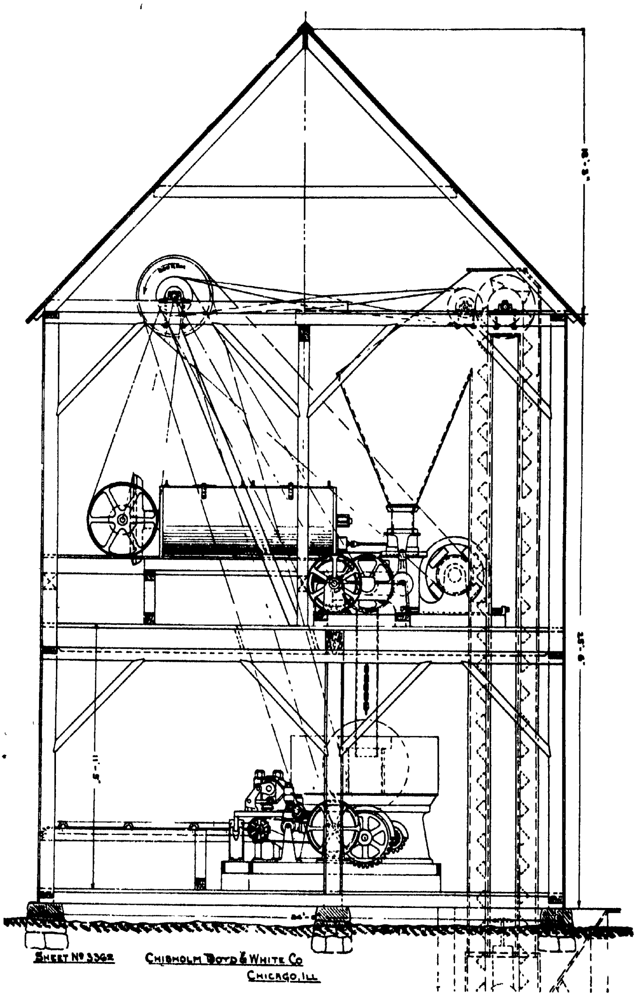

Fig. 145.—Elevation of Typical Chishom-Boyd-White Mineral Briquetting Plant. On 2nd Floor is Shown the Preparation Room; the Press on the Ground Floor.

	Lbs.
Sulphide ore	320
Lime rock	60 to 100
Briquetted sulphide concentrates	860 to 840
Coarse slag	400
Total	1,640

The raw concentrates were briquetted on a White press and the briquettes were used to flux sulphide ores containing silica in excess.

At the Missouri Cobalt Company the briquettes were made with both lime and water glass as binder, but chiefly the lime. At this plant good briquettes were made—provided they were air-dried over a period of three days after manufacture. This delay is a handicap experienced with most briquettes made with lime binder unless steam-hardened.

At the Granby Consolidated Mines in Vancouver, a similar press is now working on flue dust only, for the copper smelter.

At the Washoe plant of the Anaconda Copper Mining Company, the briquetting plant formerly consisted of two Boyd brick presses and two White briquetting presses. The operation of manufacture, handling, and drying required eight men per shift. Later, this Company substituted for the above equipment four end-cut, auger brick machines, each having a capacity of 840 tons for 48 hours. The briquettes were made of one-third first-class ore screenings, one-third slimes from the settling pots, and one-third product of the concentrate settling tanks. A small addition of washed coke was also made in order to give the briquettes porosity and open texture. The various ingredients are proportioned by men standing at chutes over the belt that serve a pug mill. It is noteworthy that the *briquetting of this ore reduced the flue dust loss of the blast furnace from 18¾ per cent down to 3 per cent.* Table XVIII shows a typical charge sheet for the Washoe blast furnace as outlined in Prof. Hofman's paper "Notes on the Metallurgy of Copper of Montana."

Well over fifty installations of the Chisholm, Boyd and White presses were made in the double decade from 1890 to 1910. Prof. Arthur S. Dwight says in *Mining and Metallurgy* for December, 1921: "The general adoption of briquetting in the late 90's gave a respite of several years to th . mechanical furnace in lead practice, because it permitted the roasting to be done on its

TABLE XVIII.—CHARGE SHEET

Name of ore	Moisture	Weight		Cu		SiO_2		Fe and Mn		CaO and MgO		S	
		Wet	Dry	Per cent	Wt.	Per cent	Wt.	Per cent	Wt.	Per cent	Wt.	Per cent	Wt.
Coarse concentrates	3.0	1,550	1,500	8.7	130	22.0	330	27.0	405	....	....	35.7	535
Briquettes	8.0	1,620	1,500	6.9	104	45.0	675	11.0	165	....	....	17.0	255
First-class ore	3.0	2,060	2,000	8.0	160	50.0	1,000	12.1	242	0.5	10	15.4	308
Converter slag	...	1,500	1,500	2.0	30	30.0	450	42.9	643	1.0	15	0.7	10
Limestone	...	3,500	3,500	...	...	5.0	175	1.0	35	51.0	1,785	...	...
Coke	...	.....	1,020	...	..	6.9	70	1.2	12	0.8	8	0.7	7
		10,230			424		2,700		1,502		1818		1,115

merits, and without being complicated by attempts to produce a coarse or agglomerated product." Later, the general adoption of blast roasting as in the Huntington-Heberlein pots and Dwight-Lloyd sintering machines caused considerable decrease in the briquetting as applied to the metallurgy of copper and lead. The present indications are that with improved and vastly less costly briquetting practice as is possible on the "Universal" roll press a returning to briquetting practice in this field may well result. In this connection the following remarks are made by Mr. Irving A. Palmer in "Smelting Lead Ores in the Blast Furnace:" "The preparation of the furnace charge is an important feature in the operation of a lead-smelting plant. Every lead metallurgist knows that the efficiency of the blast furnace is very largely dependent upon the physical character of the charge. It is a difficult problem to prepare a charge that will smelt rapidly and also produce clean slags and mattes, and that is why it is so difficult to introduce satisfactory methods for the mechanical handling of ores and by-products. It is this that makes lead smelting so widely different from iron and copper smelting. The elimination of the greater portion of the fines from the furnace charge has long been considered one of the essentials of good work. In order to avoid the evil effects of a tight charge it was formerly the custom at some plants to screen the oxidized ores, and then briquette the fines with flue dust, slimes, concentrates, and fine roasted ore from the mechanical roasters. The product of the hand roasters ordinarily was not briquetted. But briquetting is an expensive process, and the briquettes made were often so friable that they fell to powder in the upper part of the blast furnace. However, something had to be done with the excessive amount of fine material that had to be smelted, and briquetting was considered a necessary evil. The practice undoubtedly increased the furnace speed and efficiency, but it was often carried to excess. Probably the greatest advance made in lead smelting in recent years has been the general introduction of blast-roasting processes, such as the Huntington-Heberlein and the Dwight-Lloyd. In these processes roasting and sintering are accomplished in one operation, giving a product that greatly increases the capacity and efficiency of the blast furnace in which it is smelted. Sintering pots and machines have largely replaced

the old-fashioned roasters and the briquetting presses. The common practice is to sinter a mixture consisting of oxidized fines, siliceous sulphides, concentrates, slimes and pre-roasted high-sulphur ores. Almost any fine ore can be used, provided the sulphur of the entire mixture does not exceed or fall below a certain figure, which usually varies from 12 to 14 per cent. Ordinarily only high-sulphur ores and lead mattes are subjected to a pre-roasting. In the latest practice this is done in Wedge mechanical roasters, in which a large tonnage can be roasted to almost any desired degree of oxidation, using practically no fuel. The sintering processes enable the lead metallurgist to handle cheaply and satisfactorily nearly all the classes of fine material with which he has to deal, except flue dust. This latter product usually interferes with the sintering process, and, in the opinion of the writer, *should be briquetted.* If a smelting plant be properly conducted the amount of flue dust made will be small. By using a mixture of roaster and blast-furnace flue dust usually a self-binding material can be obtained. It is *also sometimes advisable to briquette high grade concentrates,* rather than to subject them to the sintering process."

To-day at the Arizona Copper Company there are no machines but the converted flue dust is hand-briquetted and returned to the converter.

The briquetting of iron ores is, in nearly all cases, done in the vicinity of iron blast furnaces and is, therefore, generally linked with the briquetting of iron flue dusts as described in the preceding chapter. Capacities of such plants must be large; the briquettes must be strong; and above all, the cost of operation must be very low. In most of the installations large piston and mold, toggle or brick presses are used of the type of the Schumacher, Tigler, or Sutcliffe. Drop or fall presses have been used as well; of these the Dorstener and Gröndal have been the favorites.

The Ilseder plant and the one at Kertsch, Russia, have already been mentioned as briquetting without binding or other material admixture—both of these installations being able to form the brick at low pressures on account of the clayey character of the ore. The installation at Friedenshuette, Oberschlesische Eisenbahnbedarfs A. G., using Ronay presses and relying on high hydraulic pressures only to briquette mixtures of ore and flue dust

of non-self-binding nature, has been mentioned in Chapter XIII.

The Gröndal process, described in Chapter XIII, has had a far wider vogue in its application to ores. The following installations have been made in Sweden: Strassa, Lulea, Guldsmedshyttan,

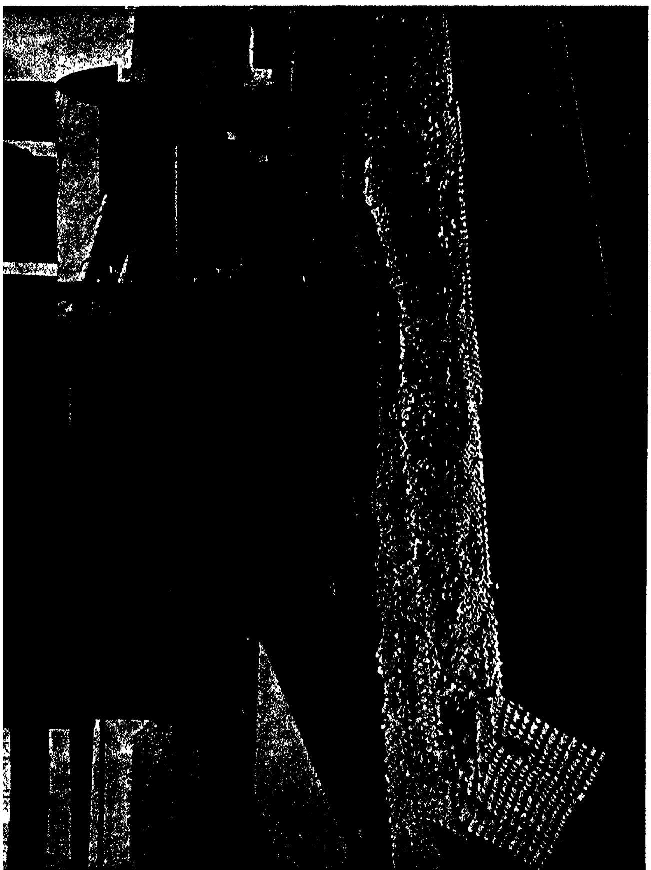

Fig. 146.—Iron Ore and Flue Dust Briquettes in Stock Pile. Oberschlesische Aktiengesellschaft fuer Eisenbahn bedarf, Friedenshuette, Upper Silesia.

Herraeng, Flogberget, Riddarhyttan, Norberg, Horndal, Sandviken, Uttersberg, Hellfors, Vigelsbo, Helsingborg. In Germany and Austria, two plants were put in at Salzgitter and Witkowitz—both of which were subsequently discontinued. In Great Britain,

installations were made at the Coltness Iron Company, Ltds., E. P. and W. Baldwin, Cromavon, and others; in Spain, the Alquife Mines; and in the United States, the Mayville plant situated in Wisconsin has already been mentioned. The percentage of iron in the briquettes is somewhat reduced, in the Gröndal process, owing to the oxidation of magnetite into peroxide of iron. This apparent disadvantage is overcome by the expulsion of sulphur, and a gain in reducibility and consequent fuel economy. Magnetite requires in the blast furnace 300 pounds more charcoal per ton of pig iron than does hematite. The Gröndal process, notwithstanding its high cost, is therefore good practice for Sweden, and other countries where charcoal and sulphur-bearing ores have to be employed.

At Alquife and Coltness the Sutcliffe press is used (Chapter II). Concerning this substitution of the "Emperor" Sutcliffe press for the fall presses, Prof. Franke of Berlin, has to say the following: "As regards the success of the Sutcliffe presses, especially in comparison with the older fall presses, the management report very favorably. The Sutcliffe press requires only few repairs, apart from the parts which get into constant and rough touch with the ore. These, however, especially the liners, can be easily renewed. The fall presses, on the other hand, require very considerable work for the upkeep of the other parts as well; the wear and tear of the parts coming into contact with the ores was 50 to 100 per cent greater than in the case of the "Emperor" presses. The latter deliver briquettes the thickness and hardness of which can be regulated during the running of the machine, and the briquettes are always close and dense with sharp arrises. The briquettes produced on the fall presses showed, on the contrary, arrises more or less out of the straight, and very often cracks, which largely contributed to the formation of ore in powder." The research department of the U. S. Steel Corporation had the same experience with drop or fall presses in working with the Gröndal process at Briquette, Pa. Plunger presses were substituted for the fall presses before the process was finally abandoned. The majority of the works in question use either the tunnel kiln, as described in Chapter XIII for the burning of the briquettes, or, the improved Hoffman as installed by the Coltness Iron Company.

This kiln consists, usually, of sixteen chambers, six chambers at each side, separated by a wall, and two chambers at each end, all connected with each other so that the fire can travel from chamber to chamber continuously. In burning, while one chamber is under fire, the waste gases pass through the other chambers charged with briquettes. The entering air passes through the burnt briquettes in the other chambers and is thus preheated while cooling them. In this way, the utmost economy of heat is

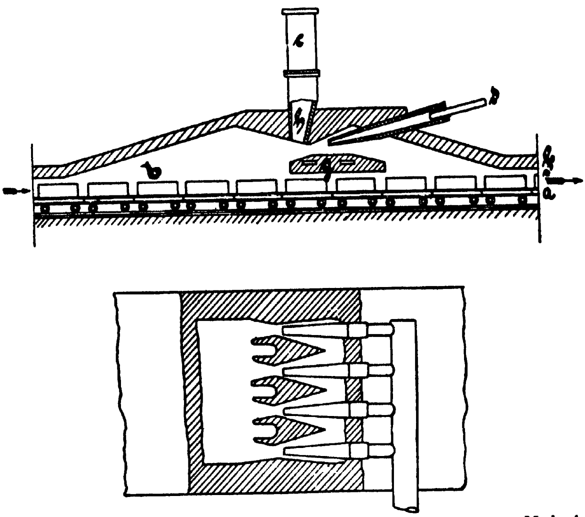

Fig. 147.—Ramen Kiln for Sintering Gröndal Briquettes as Made by Humbold A. G., Cologne, Germany.

a—Longitudinal Lug on which Cars suspend. It Serves to Prevent Hot Gases from Reaching the Car Axles.
b—Car Containing Briquettes.
c—*h*— Air Supply.
d—Burner.
f—Discharge Port.
g—Baffles for Heat Circulation.

obtained. In burning iron ore briquettes the theoretical heat requirement is that needed to drive off the moisture, sulphur, and carbonic acid. This heat quantity, along with the inevitable losses in chimney gases and radiation, should be derived from coal to the amount of 5 to 10 per cent by weight of the finished briquettes. The fritting of the briquettes is obtained at from 1,100° to 1,400° C. Preferably these kilns should be gas-fired, either with

blast furnace, or producer gas, and induced draught should be adopted in preference to chimney draught. The improved Hoffman kiln costs less than tunnel kilns of the same output. It is also more economical in upkeep. It is more efficient in the removal of sulphur and carbonic acid than is the tunnel kiln. On the other hand, its use is limited to briquettes that are strong before they are fritted, capable of bearing their own weight stacked 6 feet high. As the briquettes have to be stacked and taken out of the chambers, it requires more labor to operate than the tunnel kiln. The tunnel kiln can be used for most ores, and is the only kiln capable of burning an ore which will not make (without binder), a strong unburnt briquette, such as concentrates. It is also best adapted for use with naturally wet ores, as the tunnel kiln does not necessitate the drying of either the ore or the briquettes prior to burning.

The briquetting plant of the Pen-hsi-hu Coal and Iron Company, Ltd., is described by C. F. Wang in an article entitled "Coal and Iron Deposits of the Pen-hsi-hu District, Manchuria"—*Trans. A. I. M. E.*, Vol. 59. A summary of the account of this plant is as follows: "The concentrates from the Nan-fen concentration plant, the fines obtained from the rich ore mined (as this ore is very brittle), and the flue dust from the blast furnaces, are all three mixed in the briquetting plant. This plant is also in the course of construction at Pen-hsi-hu, near the blast furnace. It will consist of two Emperor presses to make bricks of 6¾ x 6¾ x 2¾ inches (171 x 171 x 69.8 mm.), one Sutcliffe's patent tunnel kiln 230 feet (70 m.) long and 6 feet (1.8 m.) cross-section. The kiln will be heated by means of two gas producers, until the briquettes are dry and hard. It is intended to use half concentrate and half rich-ore dust, with a small amount of limestone as cementing material."

The various methods of briquetting iron ores with binders have also been largely discussed in the chapter on flue dust, and in the main these methods are available for either blast or raw material, or both mixed, which latter is the general practice abroad. Nearly all ores require the addition of moisture at least, and in that case, as well as in the cases where liquid binders are added, the plants consist of one or more paddle mixers—a trough or troughs of suitable length carrying paddles arranged to convey

the mixing material forward—followed in some cases by a masticator from which the material is fed directly to one of the presses above enumerated. The better the mixing the more dense and solid the resulting briquette and the less the time required to obtain hardening. In general, the masticator is used where the ores or dusts are in a cellular condition requiring breaking down before pressing, but this operation is an improvement in practically all cases. The density of a briquette is affected by the amount of moisture used. In some cases high moisture produces high density while in others the opposite is true—depending on whether the ore or binding material form hydraulic cements in setting.

The Scoria process described in Chapter XIII is used for mixtures of ores and flue dust in the following plants: Friedrich-Alfred-Huette, Friedrich Krupp A. G., Rheinhausen, and A. G. for Huettenbetrieb, Duisburg-Meiderich.

Spathic ore, mixed with lime, has been successfully used as a *binding* medium. The briquettes, immediately after being formed, are exposed to steam pressure in kilns, as in the Scoria process. The hydrate of lime and carbonate of iron, when so mixed and exposed to steam pressure, are converted into hydrated ferrous oxide and carbonate of lime. The former is of a gelatinous nature and serves as temporary binder, changing with time into hydrated sesquioxide of iron. The procedure is as follows: Two parts of spathic ore with one part of lime, reduced to powder, are thoroughly mixed. Of this mix 15 per cent is added to the ore and moistened, hydrating the lime. Briquettes are then made under a pressure of about 6,000 pounds per square inch. The briquettes are packed—edgewise—on wagons, in which they are charged into steam chests and exposed to a steam pressure of 120 pounds per square inch for a period of 4 to 7 hours. Where spathic ore alone is briquetted 6 per cent lime is sufficient. The briquettes made according to this method are very good but both plant and operation are expensive.

The "Revolver" press described in Chapter II, and especially as made by Yeadon, Son & Company, Leeds, England, and William Johnson Sons, Ltd., Leeds, England, has been used to briquette Spanish iron ore, manganese ore, and purple ore, and to a less degree, copper ores and concentrates. It is claimed by the Yeadon Company that no agglomerant of any kind is required

and the ore is simply moistened and fed to the press, or, at the worst, mixed with a little lime. A plant as supplied by Yeadon consists of the following:

1. Mixer or measurer.
2. Chain elevators.
3. Double measuring spout.
4. Grinding and tempering mill.
5. Chain elevators.
6. Revolver press.

This class of plant has been installed at the following places:

The Carlton Iron Co., Ltd., Carlton Iron Works, via Ferryhill.
The St. Helens Smelting Co., Ltd., St. Helens.
The Ore and Fuel Co., Gartsherrie, Coatbridge.
The Coltness Iron Co., Newmains.
Messrs. Jas. Dunlap & Co., Ltd., Clyde Iron Works, Glasgow.
Etablissements Metallurgiques de Poissy, Poissy.
Societa Ligure Ramifera, Cestri, Italy.
The Famatina Development Corp., Ltd., Argentine Republic,
The Namaqua Copper Co., Ltd., Namaqualand.

The process of the German Briquetting Company, Altenkirchen, is installed at Friedrich-Wilhelms-Huette. The striking point of this process is the binding material, which consists of lime, cement and a soluble silicate. These briquettes require a considerable time in the open air for the absorption of carbon dioxide.

The Dahl system has been installed at the following: Gewerkschaft Deutscher Kaiser, Bruckhausen; and Rheinische Stahlwerke, Duisburg-Meiderich. The mechanical methods are as usual—the characteristic of this process being the binder, which is a mixture of hydrate lime (8 to 10 per cent) and 1 per cent of pulverized slag. These briquettes also require a long setting time in the air for the absorption of carbon dioxide.

At the Hasper Iron and Steel Works, Haspe, Germany, a system was used wherein the briquettes were made from ore, flue dust, and mixed with the mud obtained in the wet cleaning of the blast-furnace gasses. To this mixture 6 per cent calcium sulphate was added and it was claimed that the added sulphur had no deleterious effect upon the blast furnace operation. It is noted, however, that the process is expensive when applied to

ores and Prof. Weiskopf, *Stahl and Eisen*, February, 1913, recommends that it be confined to the flue dust. The Schumacher process is now in use at this plant.

The Trainer process wherein zellpech is used as binding material has been successful in briquetting mixtures of flue dust and ore at this plant. The mix is preheated with steam and the pressure used is 500 atmospheres. These briquettes are not weatherproof and cannot, therefore, be transported for long distances. They can be waterproofed by a coking heat treatment, but this is expensive.

The Crusius process in use at the Ilseder Works uses a binder of prepared tar, which has been made moisture-free and relieved of its light oils in that preparation. This process is to-day used on a mixture of ores and flue dust. For it is claimed the advantage that during the smelting the tar acts as a reducing agent and in burning out contributes to porosity.

The Schumacher process, whereby certain soluble salts, as described in Chapter XIII, added to blast-furnace flue dust produce a cementing action with the evolution of heat has been applied very widely especially in Germany to the briquetting of mixtures of flue dust and ore. This process does not apply for the briquetting of ores alone, as the reduced oxide FeO is necessary to obtain the reaction. Prof. Richards, *Trans. A. I. M. E.*, 1913, of Vol. 43, found that the limit of carrying power was 70 per cent ore to 30 per cent flue dust (one part catalytic dissolved in ten parts water being added to the foregoing). In Europe chloride of magnesium is cheap and has proved a successful catalyzer. Dr. Schumacher, of Berlin, stated that up to 60 per cent of briquettes have been used in a blast-furnace charge. The usual addition, however, is 10 per cent. The installations made are as follows:

Friedrich Krupp, Essen.

Vereinigte Huettenwerke Burbach-Eich-Duedelingen, Duedelingen.

Roechlingsche Eisen-u. Stahlwerke, Voelklingen.

Rombacher Huettenwerke, Rombach.

Gebr. Stumm, Neunkirchen.

Deutsch-Luxemb. Bergw.-u. H· etten-A. G., Abt. Union, Dortmund.

Societe John Cockerill, Seraing, Belgium.
Societe de Briquetage, Couillet, Belgium.
Wickwire Steel Co., Buffalo, N. Y.
Gelsenkirchener Bergwerks-A.-G., Esch.
Halberger Huette bei Brebach.
Dnieprovienne, Russia.
Kramatorskaja, Russia.
Hasper Eisen and Stahlwerke, Haspe.
Vereinigte Koenigs und Laurahuette, Konigshuette; Burbacher-Huette, Burbach; Dillinger Huettenwerke, Dillingen; Lothringer Huettenverein, Aumetz-Friede.

At the Gelsenkirchener blast furnace of the Hochofenschlacke the same plant makes slag stone bricks and briquettes of ore and flue dust. The press used is a toggle press made by Komnick Elbing similar to the Schumacher. Lime is crushed and hydrated; it is then mixed in a paddle mixer with the ore and flue dust and pressed. Four per cent of lime is used. After pressing the briquettes are sent to steam-hardening cylinders where they remain about 5 hours. The hardening is very thorough and the briquettes are excellent.

The patent of Ludwig Weiss, described in *Stahl and Eisen* Vol. 31, September, 1911, provides for a more rapid preparation of briquettes with lime binder by exposing the briquettes to an atmosphere of carbon dioxide. The process is carried out as follows: The ore is mixed in horizontal paddle mixers with 6 to 8 per cent of pulverized slaked lime or lime-water and the mixture is briquetted in toggle presses. The briquettes are subjected after the pressing action to the action of carbonic acid. The hardening takes place in hardening cylinders, to which the briquettes are fed in a specially designed carrier for greater space economy. The carriers are driven into the hardening cylinders on a monorail system. It is said that the hardening is finished in 3 to 4 hours. The briquettes are first exposed to cold and later to warm carbon dioxide. A plant using a system of carbon dioxide absorption has been installed at Cruzthal.

In the *Review to Metallurgy*, Vol. 9, Monsieur J. A. Auzies describes a method of briquetting iron ore and fine residues by the addition of 3 per cent quick lime to the oxide ores followed by moistening. In the ores about 10 per cent of fine wood saw-

dust or coke braize has been incorporated. After pressing in a suitable press the briquettes therein formed are exposed to a temperature of 1,200° F. to 1,500° F. The briquette was hardened, and at the same time, by the burning out of the organic matter, rendered porous.

A problem that has recently attracted a very considerable interest in research has been that of the preparation of titaniferous iron sands found in many places—especially along the Pacific coast, the St. Lawrence Valley, and on the shores of the Northern Island of New Zealand. The sands require concentration, and in some cases a large part of the titanium can be removed; in others the concentration, while increasing the iron, at the same time increases the percentage of titanium present. The Canadian sands can be cleaned by such concentration; the others retain their titanium, and the briquetting of the materials have in some instances been complicated by the attempt to find suitable flux, which, added to the binder, will serve to slag out the titanium oxide. The experiments on the New Zealand sands have proceeded somewhat along the lines of the Gröndal process, with the interesting feature that an eggette Belgian press was used in forming the briquettes prior to their being roasted in a kiln. These experiments were described by V. W. Aubel, in the paper before the A. I. M. E., Vol. 63, 1920. A Belgian type press was used to prepare the sand for the test. The sand was carried from the beach in small trucks, and fed by bucket elevator into a rotary coal-fired kiln. Thence it was discharged by a screw conveyor and elevated to the magnetic separator; after concentration the dried concentrates were mixed with 12 per cent of low-sulphur coal, and fed to a disintegrator, and thence discharged into a storage bin. From the bin a screw conveyor fed it to a Fuller mill. All the product from the mill passed through a 100-mesh sieve. From Fuller mill, after being slightly moistened, it passed into an enclosed mixing conveyor and from there to another storage bin. From the bin the material was fed by a roller feed to the press. The briquettes were discharged over shaking screen to a conveyor and were carried to the feeding platform of a roasting furnace. After roasting, they were automatically discharged over a screen, and stored for smelting in the blast furnace.

FLOW SHEET

Raw wet sand
Rotary dryer
Magnetic separator
Waste tailings } Concentrates (60 per cent Fe, 10 per cent TiO_2) 12 per cent coal added
Carr disintegrator
Storage bin
33-inch Fuller mill
Conveyor mixer (dampened with water)
Storage bin
Hendy feeder and vertical pug mill (water added)
Eggette machine
  Broken eggettes and fines back to bin by elevator
  Eggettes by conveyor belt to feeding platform of roaster
  Blast roaster (coke braize added)
  Fine back to storage bin— Roasted eggettes to furnace bins.

The success of the roast depended on keeping the temperature down to a red heat; otherwise the briquettes fused, forming large lumps, interrupting the operation of the discharge. The resulting briquettes were hard and slightly porous.

The blast furnace plant consisted of a small furnace of about 15 tons daily capacity, a 24-pipe hot-blast stove, and a 24-inch Connelsville smelter blower. Two campaigns were made in the furnace—the first for ten days, in which 90 tons of iron were made, the latter for nine days, in which a similar quantity was made. The test bars were reported by representatives of the New Zealand Railway as being better than the regular iron used in their shops. It is noted that in this case, so far as briquetting was concerned, that an eggette machine discharged briquettes made without a binder, but from material extremely fine in physical character. It is significant that the briquettes so made were strong enough to stand the handling between the press and the roasting furnace.

Another and later line of experiment has been made by William Tyrell upon the black sands of the Pacific coast in the United States. The procedure of this investigation was described by James L. Avis, Jr., in the *Iron Trade Review,* September, 1921. These tests were conducted at Sedro Woolley, Washington,

by the New Era Iron and Steel Corporation, Mr. Tyrrell's Company. The ore is briquetted with a binder and the briquettes are melted in an ordinary blast furnace.

Before making the briquettes, the black sand is jigged and thus concentrated. After jigging, the sand is mixed with predetermined proportions of lye, diatomaceous earth, sodium sulphate, and other materials. So far, the mixing has been done by shovel. The above mixture is a cohesive agent, and acts also as a flux in the subsequent furnace operation. After thorough mixing, the material is molded in troughs (6 inches wide x 3 inches deep). The bricks are placed in a dryer, and thence charged in the blast furnace. The average analysis of the briquettes is as follows: Iron, 54.0; titanium oxide, 11.0; silicon oxide, 7.0; and phosphorus, 0.018 per cent. Their average compressive strength is high. The strength increases as the temperature rises and does not start to decrease until closely approaching the fusion point. The briquetted ore, coke, and limestone are charged to the blast furnace in proportions of 47, 47 and 5 per cent, respectively. No trouble has been experienced in building up the hearth, as is usual in smelting titaniferous ores. This is explained by the fact that the titanium and chromium contents are slagged by the binder's action. The experimental furnace has a capacity of 10 tons, is 35 feet high and has an inside hearth diameter of 30 inches. The hot stove is 30 feet high, 5 feet 6 inches in diameter, and contains four rows of four 6-inch pipes. The product of the blast furnace is cast into pigs of 4 x 2½ inches. The analysis shows 2.75 per cent graphitic carbon, 0.98 combined carbon, 0.60 phosphorus, 0.08 sulphur and 1.25 silicon. Gray iron made from it is dense, strong and has good machining qualities. Steel castings were produced in the electric furnace from a mixture of about 39 per cent open hearth scrap, 44 per cent foundry scrap and 16 per cent black sand pig iron. The castings were clean, homogeneous, and machined satisfactorily when annealed. The carbon content was 0.28 per cent and the tensile strength averaged 69,000 pounds per square inch.

As to the adaptability of ore briquettes for blast-furnace practice, the requirements have been excellently summarized by C. de Schwarz, of Liege, Belgium, in a paper before the Iron and

Steel Institute of England. These requirements which every process must fulfill to be successful are given by him as follows:

1. The iron ore briquettes must have a certain resistance against mechanical influences. They must resist a pressure of not less than 2,000 pounds per square inch, and, when dropped from a height of 10 feet on a cast iron plate, they must not fall into dust, although they may break into pieces.

2. They must resist heat. Heated to 900° C. they may commence to sinter, but they must not distintegrate into small fragments.

3. They should be capable of being placed in water for an appreciable length of time without softening.

4. They must resist the influence of steam at 150° C. without crumbling.

5. They must possess a certain amount of porosity, in order to allow the carbon monoxide in the blast furnace to penetrate the interior of the briquette and to exercise its beneficial reducing influence. In order to test the briquettes for porosity, they are, after being dried, placed for about 25 minutes in water, during which time they ought to absorb not less than 12½ to 16 per cent of water, according to the nature of the ore.

6. The binding medium, if any is used, should not contain noxious substances (sulphur, arsenic) to such an extent as to be injurious to the quality of the pig iron produced.

7. The cost of producing briquettes should not exceed the difference in the prices between lump ore and fine ore.

II. The Briquetting of Ores for Volatilization.—Iu retorts or furnaces the briquetting of ores and metallurgical by-products as a preliminary to volatilizing in retorts has been essentially a feature in the zinc industry of constantly increasing importance. Especially does it apply to the manufacture of zinc oxide directly from the ore. There is probably no reason why any metal whose smelting depends upon its volatility, should not be improved as to its metallurgical practice through the medium of briquetting. So far, however, application has mainly been made to zinc, and especially to the manufacture of zinc oxide.

Zinc oxide and leaded zinc oxide are usually produced in the United States by the Wetherill process. In this process a perforated grate is charged with a layer of buckwheat coal (anthracite if possible). This layer is ignited and a draught forced through it. Upon this layer is charged a mixture of finely divided zinciferous material and fine coal. At the appearance of greenish flames, "zinc candles," it is known that the zinc oxide fumes are being made and the products of distillation are conveyed through cooling rooms to a bag house where they are caught in the bags. On completion of fume production, the residue is sintered together, broken by rabbles, and scraped out of the furnace.

It has been found that by briquetting the charge prior to loading into the furnace, great advantages are gained. The blast of air is driven through at a considerable less expenditure of power and does not, in the case of the briquetted charge, drive dust into the fume. Not nearly so much labor is required for working, and rabbling of the charge to break up blow-holes becomes unnecessary. A considerable addition to the amount of recovery of values is enjoyed and working conditions are far better. In fact, there are few industries to which briquetting carries so much of benefit as to the manufacture of zinc oxide.

Although the Wetherill practice was not used in Germany, the progress of briquetting in general in that country was soon felt in the zinc industry. About 1908 Hermann Pape devised a method of burning zinc out of the Oker slags in which he used a special vertical furnace of his own design. This method was an immediate success and is still in full operation. The raw zinciferous material is mixed with coal fines or coke braize, together with proper proportions of necessary flux—such as lime or sand. An agglutinant—such as coal tar or pitch is added, if the mixture in itself cannot become sufficiently hard after it has been pressed together. After the charge has been ground and mixed it is molded into briquettes. The zinciferous material is mostly slag bought from outside, made usually from a lead-zinc-ore, but sometimes from zinc-lead-copper ores. The slag is broken by a stone crusher and falls in large underground pits of 3,000 tons capacity. From here it is taken by bucket elevators to two

ball mills and ground down to powder. Pitch and coke are also crushed and all three: metalliferous slag, coke, and pitch, are mixed in a paddle mixer and lifted to an overhead bin, whence the mix is taken to the press. The mixture is heated by steam in a vertical fluxer and then briquetted in a Belgian roll press. The briquettes weigh about 1 pound each; from here they are taken by conveyors to storage bins. The briquettes harden quickly after a run of about 80 to 100 feet. The mix is in the following proportions:

81 per cent metalliferous slag or zinc ore.
14 to 15 per cent coke.
5 to 4 per cent pitch.

At the Oker Installation, 160 tons of briquettes in two 8-hour shifts are made daily. From the storage bins, the briquettes are taken by a monorail with clam-shell bucket to the charging floor of the furnaces. The monorail also brings the coke. There are twenty-six furnaces in two rows, about sixteen are always running, the other one is repaired in the meantime. The prepared charge is then delivered to furnaces, continuously charged from above. A powerful blast of air is passed through the charge, regulated so that the charge is heated to a red glow on its upper surface. The metallic vapors which rise from the lower part of the charge burn to oxides at the upper surface. Air is admitted in the melting zone and a quantity of lump or briquetted carbon is added to the charge. Thus the necessary temperature is maintained in the melting zone. At the high final temperature, the ore from which the zinc has been removed is melted to a liquid which is blown out from the lower part of the furnace. The zinc oxide is collected in bags in the usual manner.

Wilhelm Witter, working in Hamburg also about 1908, brought out a process which was in effect an adaptation of briquetting to zinc smelting in a reverberatory furnace. The Witter's briquettes were made with a mixture of coal dust and briquetted preferably on a roll press. In the reverberatory furnace they were subjected to a temperature of 950 to 1,180° C.

H. L. Sulman and Picard developed a process in London about 1912 for a similar application of briquettes to zinc oxide manufacture. They specified a briquette in which sodium carbonate

or hydrate was added as additional flux. The zinc smelting test of zinc briquettes made of Broken Hill concentrates was made during 1910 under the auspices of the British and Foreign Construction Company and was reported in the *Engineering and Mining Journal* of August 13th, 1910, by Theodore J. Hoover, E. M. The concentrates were analyzed as follows: Zinc, 31.70 per cent; lead, 24.38; manganese, 1.69; lime, 1.18; alumina, 1.74; silica, 8.08; oil, 0.40; and loss, 0.26. The silver content was 24.7 ounces per long ton. The briquettes were 5¼ x 4¼ x 8 inches. They were arranged two deep, seven long, and one wide, leaving a space about one-fourth inch between the retort and the briquettes. The retort was of the Welsh type. One furnace held one hundred and forty-four retorts in six rows of twenty-four each. The briquettes were brought to the furnace on cars. The charging was done by three men. All the zinc hands who had experience with charging briquettes prefer them to the loose charging system because of the cleanliness and minimum labor involved. The distilling gave no difficulty. The furnace was run a little cooler than on the ordinary run. The briquettes came out of the retort porous and intact, a material excellent for direct lead smelting. There was no slagging up in the bottom of the retorts. The spelter produced was excellent, assaying 99.25 per cent zinc and 0.73 per cent lead. The weight of the burnt-out briquettes was about 75 per cent of that of the raw ore. Both the lead and silver were held in the briquettes during the distillation. The residues assayed 6 per cent zinc, 28 per cent lead and 30 ounces silver per ton.

In the United States, about 1912, considerable attention was given to the application of briquetting of zinc ore for the manufacture of zinc by distillation in clay retorts. It was found that briquetting the charge increased the capacity of retorts, and by the increased density of the charge, lowered the difficulty of heat transfer, and thereby reduced smelting time. When the Brooks' process is used there is also a very great decrease in the "blue billy" production on account of the element of salt filtration. For this reason, and for the increased density and space economy, the increased capacity of each retort is approximately 50 per cent. George S. Brooks, of Depue, Illinois, patented a process for making and using briquettes of zinc ore which was

installed by the Mineral Point Zinc Company at Depue, Illinois. The practice at this plant is carried on as follows: The briquette is made of four parts by weight of crushed zinc ore; one part of finely powdered ore, or commercial zinc oxide, one and one-half parts of fine coal, and a sufficient quantity of sodium chloride solution to form a plastic mix of the above ingredients. The amount of salt solution is usually one-half to one per cent, in weight of the amount of ore in the mixture. The ingredients are thoroughly mixed in a paddle mixer and formed into briquettes in a press. This installation has two types of press—a Schumacher (see Chapter II) toggle press, and a brick press (American Clay Machinery Co.) The Schumacher press forms the material into briquettes, approximately 7½ inches in diameter, which is slightly less than the internal diameter of the cylindrical retorts in which they are used, and about 3 inches in height. After the briquettes are formed they are delivered to a kiln and dried for a period of about 24 hours at a temperature of about 220° F. As a result of this operation the salt forms a hard crust about the surface. The salt shell is both a briquette binder and a filter for the zinc fumes during distillation, and its presence causes an increased production of spelter and a lowering of the amount of "blue billy" produced. The briquettes are charged into the retorts of the furnace with a charging tool. The charging tool is filled with a supply of briquettes and then applied to the mouth of the retort, and the entire charge of briquettes is pushed bodily into the retort.

Mr. Parker C. Choate has investigated the use of briquettes especially with the view of direct decomposition of zinc sulphide by lime. Mr. Choate's process calls for the manufacture of a very dense briquette by a very hard pressure with the utmost homogeneity of mix and extreme denseness of the briquetted mass.

In a paper before the A. I. M. E., February, 1918, Woolsey M. Johnson reported a series of experiments in zinc distillation wherein the briquettes were made of the fine ground material briquetted with coal. A large net saving in the metallurgical practice was indicated. The binder used in this briquetting was acid sludge from the oil refineries, used in amounts of 10 per cent to 12 per cent.

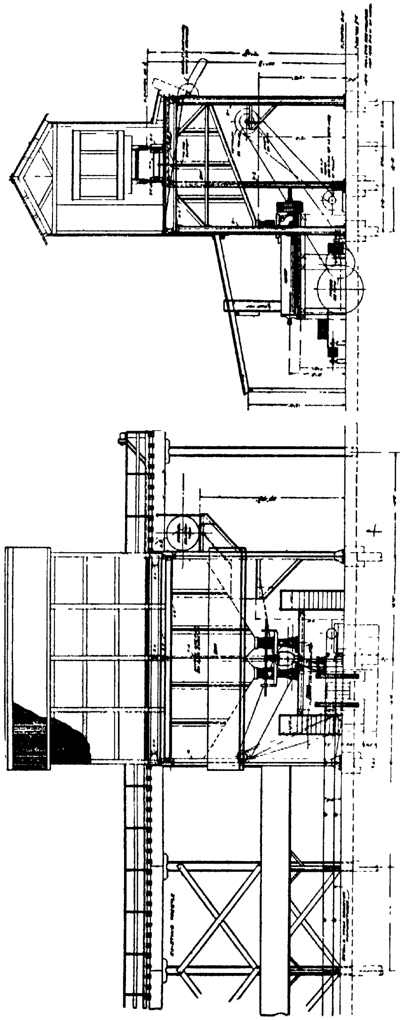

Fig. 148.—Typical Layout of Schumacher Ore-Flue Dust Briquetting Plant with Schumacher Type Press.

The largest installation in the United States, and possibly in the world, for the manufacture of zinc oxide wherein ore and fuel are briquetted, is located at the works of the New Jersey Zinc Company at Palmerton, Pa. The process used for briquette manufacture is a modification of the Kippe German patent and the Dutch process for coal. Sulphite liquor is used as a binder and the acid in the sulphite acts upon the ore, forming the zinc oxide to which the bulk of the cementing quality is due. The metallurgy involved is covered by a series of patents in the names of: James A. Singmaster, Albert E. Hall, Frank G. Breyer, George R. Waltz, and others, all assigned to the New Jersey

Fig. 149.—At Right—Zinc Ore (Plus Coal) Briquetted Ready for Charging on Wetherill Grates. At Left—Residue after Zinc is Distilled from Zinc-Ore Briquettes. Plant of New Jersey Zinc Company, Palmerton, Pa.

Zinc Company. In a word, the entire process covers the adaptation of zinc ore briquettes (made up with a carbon admixture) and anthracite coal briquettes in Wetherill furnace practice.

Instead of charging the grate bottom of the Wetherill furnace with a layer of fine coal a bed of anthracite coal briquettes is charged. The briquettes become ignited by the residual heat of the preceding charge, and when they have been brought to well-developed combustion, the working charge is added, preserving, at the same time, the uniform air passages which the coal briquettes provide over the entire surface of the hearth for the upward passage of the blast. The working charge is made up by briquetting a

mixture of the reducing agent and of the zinciferous material. As an example of the practice, 900 pounds of coal briquettes are spread out on a Wetherill grate (111 square feet). When these reach a yellow heat, 8,000 pounds of briquettes made from the mixture of reducing coal and zinciferous material are charged upon them. A much lighter blast is used than in the usual Wetherill practice. The residues are withdrawn in about 8 hours. The zinc oxide is formed by introducing an air current on the distilled vapors and the oxide is collected in chambers or bags. The same amount of labor is employed for withdrawing the residues as for the usual 6,000 pounds Wetherill charge. The clinker of the residue is far less tenacious to the furnace walls.

The briquetting plant consists of the usual Dutch process layout—proportioning devices, paddle mixer, masticators, and Belgian press (see Chapter X). It is interesting to note that the two masticators are set in series, one above the other so that all the briquette mix passes through each. The coal used is anthracite dust or slush. To 800 pounds of anthracite dust, 67 pounds of the concentrated sulphite liquor of 30° Bé is added. The two are mixed first and later 960 pounds of finely crushed zinc ore (averaging 20 per cent zinc oxide and 16 per cent silica) followed by 480 pounds of dust ores (23 per cent zinc oxide and 8 to 9 per cent silica). The figures above are relative and designed only to show proportions. The ores are generally the characteristic Willemite or Franklinite from the Franklin Furnace mines, and carry from 1 to 6 per cent of moisture, together with a certain proportion of calcite. The mix of ore, coal, and binder proceeds to the masticators, and after a period of mastication, goes to the briquetting press according to the most modern coal briquetting methods. In fact, this plant is located quite close to the site of the Lansford operation of the Lehigh Coal and Navigation Company and the plant of that company was thoroughly studied by the New Jersey Zinc Company's engineers. The presses used are of the Belgian type made by the Vulcan Iron Works. The briquettes are pillow-shaped with rectangular base 1¾ inches on the side. The capacity of the plant is about 500 tons per day. The practice to-day is to run coal briquettes for the ignition charge and zinc plus coal briquettes for the regular charge alternately.

The briquettes (averaging between 5 and 10 per cent moisture for the mixed charge and up to say 15 per cent moisture for the coal briquettes) are placed in baskets approximately 30 inches x 20 inches x 4 inches of sheet iron with bottoms of one-half inch wire mesh. The baskets, filled with briquettes, are mounted on buggies, carrying twelve baskets in four tiers of three baskets each, which are pushed into a tunnel dryer of the direct coal-fired type. The briquettes remain in the dryer from 1 to 2 hours, at a temperature of approximately 200° C. The dried briquettes are then removed from the dryer, cooled and stored, under cover, for subsequent use, as above outlined.

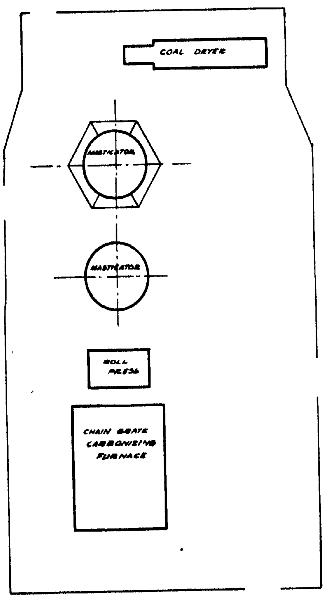

Fig. 150.—Layout Plan of the Briquetting Plant of the New Jersey Zinc Company, Palmerton, Pa.

Another volatile substance, whose briquetting should be subject to a research not yet conducted, is *iron pyrites*. It is at present far cheaper and more satisfactory to burn lump pyrites in sulphur burners, than to burn the fines, for which special and highly expensive installations have to be made. By briquetting the fines, and especially if a lime binder is used, it might be expected that the spall burners could be used to greater advantage and economy.

III. Briquettes as Electrical Resistors in Electric Furnace Smelting.—The use of a briquetted charge in electrical smelting has been the subject of considerable research. In Chapter III some attention has been given to the use of metal briquettes in electric melting. The actual value of briquetting applied to smelting in the electric way is not so-marked, or, at least, is a matter concerning which we have still much to learn. The most striking

utilization of briquetting principles in the smelting of ores has been applied to zinc—specifically to zinc smelting.

The Fulton method, invented by Dr. Charles H. Fulton of the Case School of Applied Science, was patented by him early in 1916. The principle of the process lies in the vaporization of the zinc content of zinc ores by passing the electric current through briquetted resistors, whereby sufficient heat is generated to vaporize the metal. Dr. Fulton's furnace has been set up at East St. Louis, Mo. The apparatus and methods are as follows: The furnace is of the electric resistance type. It consists of a cylindrical steel shell, closed at the top, lined with refractory brick. The bottom is open and rests on a fixed base. Flues in the base are heated by a gas flame. The dried ore, mixed with coke and pitch, is formed into briquettes (9¼ inches diameter x 21 inches long), which are used as resistors. The electric current passing through them generates heat, which raises the furnace to the temperature necessary to reduce the zinc compounds and to vaporize the zinc metal content. Coke is the best reducing agent for the briquette mix, because it contains little volatile matter. The briquette retains its form and stability throughout the process.

The briquettes are set upon the bottom electrodes, and the top connections made. A preheated retort is lowered over the briquette columns (Figure 150) and current turned on. But little energy is used until the retort reaches a temperature of from 700° to 800° C. Then the current consumption increases rapidly until the distillation point is reached. The products of the reaction are zinc vapor and carbon monoxide, in approximately equal volume. They are drawn off through openings at the top of the base and discharged in comparatively pure condition into a condenser. After 5½ to 6 hours the distillation is complete.

In making briquettes for these experiments the ore and coke in proper proportions were moistened and thoroughly mixed in a horizontal paddle mixer and stored in bins. The proper amount of coke for different types of ores is, approximately as follows:

	Per cent of weight of ore
Willemite	30 to 40
Franklinite	70 to 80
Pure mascot ore	70 to 75
Canyon City ore	60 to 70
Missouri silicate ore	85
Zinc dust	70

The mix was fed as needed to a Bartlett-Snow kiln dryer, provided with plows, and was heated to 250° C. Thence it was discharged into a hopper, from which it was dropped into cars of 500 pounds capacity; the cars were picked up by a crane and discharged into a paddle mixer, wherein the required proportion (10-15 per cent) of molten pitch was added and mixing continued about 5 minutes. The mixture was discharged into a brick-lined car kept at a temperature of about 250° C. From the car the mix was fed into a mold. The bottom of the mold was closed by a steel disk 1.5 inch thick. The mold was then tamped nearly full of the mixture, which now had a temperature of 160° to 175° C. The filled mold was transferred to a press, which consisted essentially of an adaptation of a railroad jack used in the inverted position. The remaining space in the mold was filled with the mix, a top plunger was inserted, and the mix compressed up to 1,000 pounds per square inch. The weight of the mold and its contents rested on a bottom plunger. Hence both top and bottom pressure were obtained. After pressing, bolts holding the mold together were released and the mold removed from the briquette in sections. The briquette was placed on a car, where it was allowed to cool and set.

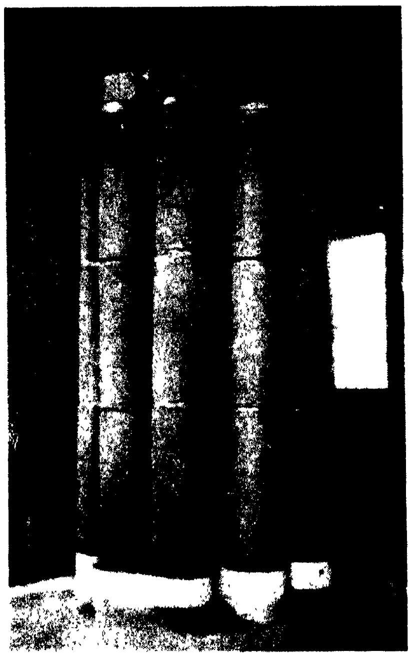

Fig. 151.—Briquetting Charge of Zinc Ore Ready for Electrolytic Treatment by the Fulton Process.

The briquettes were then baked. They were set on cars, each holding twenty briquettes. Around each briquette was placed a sheet-iron cylinder 12 inches in diameter and 26 inches high, and the space between the briquettes and the cylinders was filled with crushed coke. The car was then placed in an oven. The arrangement was such that the products of combustion from the Bartlett-Snow dryer passed both over and below the baking oven in flues specially constructed. The baking continued for 7 hours. The end temperature was approximately 500° C. A briquette so baked is very hard and firm. During baking the pitch binder softens and the briquette passes through a weak stage, at about 100° C. Briquettes from ore, coke, and pitch become conductors at 450° to 500° C. Briquettes in which a portion of the coke is replaced by bituminous coal do not become conductors until 620° to 750° C., depending on the proportion of coal so added. Briquettes where the coke is replaced by anthracite do not become conductors until 1,150° C. This is too high for the proper working of the process.

The indications are that with the development of the open feed roll press (see Chapter II) and its very evident adaptability to flue dust and ore briquetting, that installations of this sort will be the future practice in the agglomeration of ores. Certainly, the briquetting of ores by this method, either with or without the flue dust, by "corrosion" or cheap binder methods, seems to be the cheapest and most satisfactory method for preparing such fine materials for blast smelting. Whether electrolytic methods can, in the future, justify their higher costs by purer and, therefore more valuable products, remains to be seen.

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CHAPTER XV.

LABORATORY RESEARCH IN BRIQUETTING.

APPLICATION OF BRIQUETTING TO CHEMICAL ENGINEERING.

It is the laboratory result, multiplied in plant design and operation, that makes industrial progress. However, it is not unusual to see an excellent product, painstakingly evolved by the research department, fail in commercial production, not from anybody's fault, but because some unforeseen quirk developed in quantity production.

The science of briquette manufacture, perhaps more than other chemical and metallurgical industries, has many problems still in the experimental or laboratory stage.

As shown in the preceding pages, the science of briquette manufacture does not confine itself to the conversion of anthracite culm into merchantable fuel, although that problem has, indeed, held the center of the stage for years. Wherever and whenever a fine material is produced as an incident to operation—a fine material whose return to coarser size would be of benefit—a field is open to this most modern of sciences. Such problems are becoming increasingly numerous in these days of enforced economies. Summarized, wherever the blast furnace or stack smelter operates, fine ores and dusts are a detriment, clogging the blast and slowing down operation. Wherever fuel is sized, whether anthracite or non-coking soft coal, the agglomeration of the fines into domestic sizes is highly desirable. Wherever a saw or planing mill is operated, the sawdust and planings present a conundrum for salvage. Wherever lathes, drill-presses or milling cutters are shaping metal product, a pile of fine metal turnings or millings develops whose disposition has heretofore proved vexatious to the melter. In addition the manufacture of chemicals, the plants that call for the services of the chemical engineer are not without their problems of fine material treatment.

So there continues to be need for specialized research in briquetting. The field has become wide enough to constitute an engineering specialty. It cannot be said that anyone can at a glance advise a method for returning a low-value fine residue to a high-value larger size—still less the best method. Certain

problems in the field are now adequately answered—that is, commercial equipment, thoroughly standardized, has been installed, and has made quantity production at a cost well below the selling figure of the briquetted product. Specific instances covering a wide field have been detailed.

Summarized, we find hard and soft coal, blast-furnace flue dust, certain ores and the light scrap of steel and brass alloys are to-day being briquetted successfully on a commercial scale, while foreign practice shows in addition peat, lignites, sawdust and the light scrap of iron, aluminum and other metals. The latter are entering into commercial operation in the United States.

Metallurgists and fuel experts conducting their own briquetting experiments have found a scant bibliography to help them and a paucity of available apparatus and experience. A chemical and physical laboratory with appliances added for the purpose of experimentation in briquette making has been found to give much of value.

In briquette manufacture probably more than in any other field, the laboratory product is of superlative excellence. Whatever the material, a closely supervised preliminary treatment by hand, whether mixing, shredding or mastication, coupled with the painstaking molding and pressing on a laboratory hand press, results in an ideal product difficult to reproduce commercially on a large scale. This fact has been made use of by uninitiated and unscrupulous alike, in the production of high-class samples for use in the flotation of stock sales for briquetting plants, especially in the coal business. For these reasons a laboratory for research in this field should be able to discount its own excellent results and, if possible, be prepared to demonstrate the feasibility of production on a commercial scale and that, too, by actual trial.

The first and most important question of all in determining the possibility of briquetting any given substance is the difference in value between the briquettes and material from which they were made. In the beginning of research a definite answer is usually impossible until a reasonable quantity of briquettes have been made, and their use demonstrated by consumption under existing conditions. For instance, it is well to know, if possible, the price per ton one can obtain for coal briquettes as

opposed to coal dust, before establishing a manufacturing plant. The other questions which a client of a briquetting engineer might ask and reasonably expect an answer are as follows:

1. Can this material be briquetted at all?

2. Can it be briquetted by pressure only, without the use of binder or chemical reagent?

3. Does the material require cleaning, crushing, screening or other preliminary treatment prior to the briquetting process?

4. If pressure only suffices, what pressure gives the best commercial briquette?

5. What shape and size briquette is best suited to the requirements?

6. If binder is necessary, what kind is most advisable and in what quantity?

7. If chemical reagent is necessary, what kind is most advisable and in what quantity?

8. What is the best method of admixing the binder or chemical reagent?

9. What other preliminary treatment such as grinding, heating, mixing, mastication or combinations of one and all of them will be advisable before the material goes to the press?

10. What type of press is best adapted to the purpose in hand?

11. What scale of operation would be most lucrative?

12. What methods should be adopted for most economical handling of briquetted material?

13. Under what conditions are the briquettes to be consumed?

14. What will be the cost of a plant and its elements?

15. What will be the total cost per ton of briquettes produced?

For some of these questions the answer can be found in a small laboratory; market conditions, supply and demand answer some others without scientific investigation; but for the remainder, and especially for the points 9, 10, 12 and 15, a run under conditions closely approximating commercial is exceedingly desirable. Frequently such short runs can be arranged in operating plants.

A briquetting laboratory should be built with a comparatively inexpensive installation to supply answers—by deduction at least—to practically all the above questions. For installing such a laboratory, the following equipme..t would be necessary or at least desirable:

a. Crushing Equipment.—Although most of the material delivered to a briquetting laboratory for research would appear in fine sizes, there are exceptions, and the laboratory should be prepared to break up comparatively large pieces. Ordinarily, this can be done by hand hammer followed by treatment in the laboratory edgerunner or masticator.

b. Laboratory Masticator.—This usually consists of a stationary pan over the bottom of which revolves a single roll with plow set at right angles to it. It is advisable to have facilities

Fig. 152.—Laboratory Masticator for Use in Preparing Briquetting Mixes. Laboratory of the General Briquetting Company, New York.

for heating the pan by gas flame so that hot or cold mixes can be made as desired. This apparatus fulfills a three-fold function. It can be used for dry crushing. It is a very efficient mixing device both for solids plus solids and solids plus liquids; and when solids are mixed with liquids the prolongation of the treatment has the effect of mastication familiar in the Dutch process of coal briquetting (Chapter X). The machine should be in-

stalled with adjustable speed and, the larger the machine,—within laboratory limits of course—the better. For pulverizing, it will do the work on all except tough or pliant material: metal turnings, wood planings and the like, and these can be prepared in sample lots for the press by the use of shears.

c. *A full set of screens* is very necessary. Sizing tests are very usual in briquetting practice. It is very often of importance to discover what proportions of various sizes enter into a given briquette. Again, it is frequently required that all the material entering a given briquette should be of a given size or below.

d. A small *Rotary Furnace* either oil or gas fired should be installed. In metal briquetting investigations such a furnace serves as a de-oiler and cleanser and, if necessary, annealer. Run at a lower temperature, it can be used as a dryer. Many materials require pre-heating prior to pressing, for which this apparatus is well adapted. Again, many materials require an after-treatment—drying or carbonizing after pressing—and this furnace serves well such purpose provided the rotary effect is not too severe upon the briquettes—and it usually is not. Where the briquettes are delicate, a stationary oven must be used. This rotating furnace should be provided with a pyrometer and should have a wide range of temperatures and variable speed control.

e. A small *Magnetic Separator* is always useful—especially to cleanse non-ferrous metal chips of iron.

f. While the various classifiers: miniature tables, jigs, etc., are generally not required in a laboratory specializing in briquetting practice, it is often of benefit to have some sort of *Concentrating Apparatus* at hand.

g. The trial horse of the briquetting laboratory is the *Hand Press.* A good form consists of upper and lower platen; the upper being stationary while the lower is controlled by an oil hydraulic system operated by hand. Between the platens are inserted a mold and plunger containing a charge of the material to be briquetted. The mold is a hollow steel cylinder with adjustable base fitting tightly to it. The plunger fits snugly into the cylinder space. The mold is filled and the plunger set on top of the charge, mold and plunger are placed between the platens of the press and pressure applied as desired up to a maximum of 20,000 pounds per square inch. After full pressure has

been applied; the turn of a valve releases pressure, the mold and plunger containing the newly-formed briquette are removed, the mold base is lifted from the mold, and mold and piston are returned to the space between the platens, the piston now at the bottom to serve as an ejector. Above the mold in the new position is placed a stop block of convenient shape, which keeps the mold from rising under the pressure, but permits the briquette to rise. As the plunger emerges with the briquette thereon, the pressure is released and the briquette taken from the apparatus. Figure 153 illustrates a laboratory press used by Dr. Waggaman of the Bureau of Soils in investigating the briquetting characteristics of Florida phosphates. This design is a distinct improvement over the one described in that it permits the manufacture of four briquettes at once, and the ejection of the briquette downward through the platen—thereby avoiding the more cumbersome operation of removing the mold and returning it to the press in the reversed position.

h. A Hardening Cylinder. A small hardening cylinder should be installed whereby flue gases, live steam or superheated steam, as desired, can be admitted for treatment of briquettes contained within the cylinder. Especially is this necessary where lime is used to secure a binding effect—in order to accelerate the setting.

i. A minimum sized *Roll Press* is extremely useful. Earlier in this discussion it has been pointed out that the laboratory product of briquetting is usually far better than the product of commercial manufacture. A large part of this superiority is the difference between the hand press and roll press briquette. Batches mixed twenty pounds at a time in the small masticator and then dropped into the roll press would, assuredly, give a better line on probable manufacturing results—at least where roll-press practice is anticipated. The briquettes will still be superior for the reason that laboratory mixing is always very careful and thorough. On the other hand, the run through the roll press in batches produces a far greater quantity of fines—due to necessarily inefficient feeding of the rolls—than does regular manufacture on the same equipment.

j. A laboratory *Retort,* with condensers, receptacles, piping, and miniature gasometer, is a valuable adjunct to a briquetting

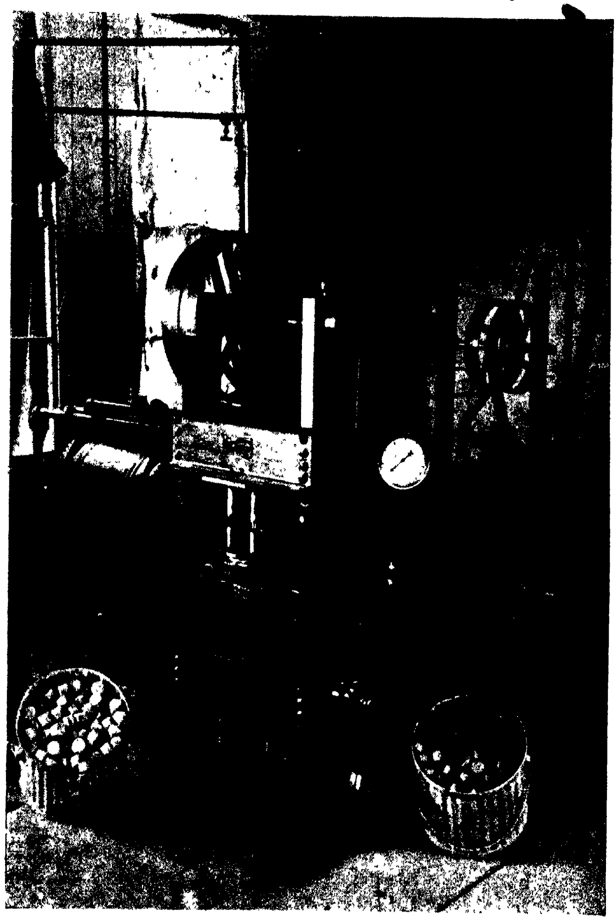

Fig. 153.—Laboratory Briquetting Press Used by the Bureau of Soils in Making Briquetting Tests on Mineral Phosphates.

laboratory. Very frequently, especially in the case of fuel investigations, the problem occurs of determining by-product yields from given bituminous or ligneous fuels, accompanied by the inquiry into the manufacture of smokeless briquettes from the carbonized residue. A retort, as above mentioned, whereby

such wood or coal could be distilled destructively and the products measured and appraised, gives to the laboratory a parallel to those low temperature carbonization methods in which interest is now developing so rapidly. Again, where simple carbonization of the briquettes is not sufficient and it is necessary to determine the value or lack of value of distillation with by-product recovery from the briquettes, such an installation is the only low-cost means available. For such purposes a very convenient apparatus is the Pritchard retort (illustrated in Figure 154).

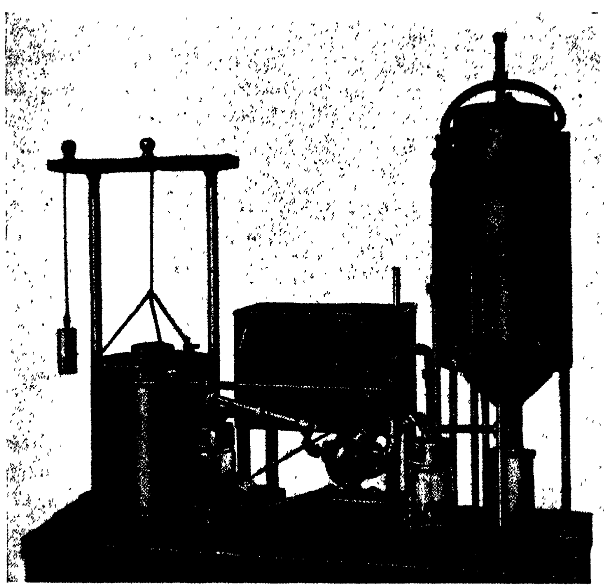

Fig. 154.—Research Model Whitaker Pritchard Destructive Distillation Process.

The retort proper consists of a vertical cylindrical metal shell heated at the sides with gas burners, a temperature measuring device being connected at the top. The charge is set in the retort in a perforated container whose sides do not touch the retort sides, thereby obviating the possibility of over-carbonization at contact points. The products of distillation are drawn downwards through the retort, passing through the charge, by means of a suction fan inserted at a convenient place in the line. Beneath

the retort is a container wherein are deposited such portions of the distillate as condense without needing the condenser coil. A small condenser coil immersed in water occurs next in the line, serving to liquefy parts of the distillate, which are deposited in the container just beyond. Beyond this container the fan is usually located and, as the action of its blades have a scrubbing effect upon the gas, another container is set just beyond to catch the liquid here deposited. From here the gas passes to a Y in the pipe, where it is split into two parts; one part going to the gasometer and the other being returned to the retort. It will be noted that at practically all times the distillation takes place in an atmosphere of neutral gas, so that oxidation of the products is impossible. The retort is so constructed as to give an even heating all the way through the charge and the lowered vapor tension within the retort permits the distillation to continue at lower temperatures than would ordinarily be required. After a run, the residue in the retort, the products in the containers, and the rise of the gasometer are measured.

Let us assume that this research laboratory is faced with three concrete problems—namely, the briquetting of materials marked *A, B, C.* Let us further presume that none of these materials has ever been briquetted at all. It is required to determine whether their briquetting could be accomplished with satisfactory commercial results.

The following procedure on the part of the laboratory is characteristic. As no previous experience in briquetting applies to these materials, one and all are tried on the laboratory hand press, using pressure only (without admixture), to see whether or not a binder is required.

Let us suppose that material *A* is a fine metal and gives a good briquette in the hand press at 10,000 pounds pressure. Material *B*, partaking of the nature of a fuel, gives no briquette under pressure without preliminary treatment or admixture. Material *C*, designated as a by-product of chemical manufacturing, also fails to give a good briquette with pressure only. At this point the indications are as follows:

Material A. This material will readily make briquettes along the approved commercial lines now adopted for metal briquetting. If the laboratory man has 30 or more pounds of this material at

hand, he should if possible arrange to make a briquette on a commercial hydraulic briquetting press. If more material is available, he makes a series of briquettes showing results at varying pressures. A good briquette out of this press would show definitely that metal briquetting practice is adapted to the material at hand.

Material B. This material presents a problem not quite so simple. The laboratory man tries all the various known commercial binders, still working with laboratory equipment and hand press to find out which binder is best. He further determines the proper treatment—heating, mixing, mastication or the combinations necessary to prepare the materials for pressing. In other words, the best way of inter-compounding the material with its binder. After this mixture is completed, short runs should be made on the hand press and the rotary press and comparison made of the products.

Material C. This material presents an interesting possibility. It is possible that the addition of a metal-salt solution may set up cementing action in the material so that it will bind under pressure. A series of known solutions are tried and briquettes made in the hand press. If a chemical action takes place (indicated by heat), the material is probably similar in chemical behavior to iron blast-furnace flue dust.

We may presume that one of these solutions on Material C has shown a result similar to that produced by ferrous sulphate at Wickwire (see Chapter XIV). In the hand press small runs are made by pressures varying from 1,000 to 20,000 pounds per square inch to ascertain at what pressure the cementation attains the highest efficiency. If cementation fails, the experiment is repeated with available binders.

The following is a typical laboratory report:

Job No. 2000. *Date*: January 1, 1900
Material:—Lead vanadate. *From*: Blank Corporation
Condition:—Mixed with 15 per cent of soda ash.
Quantity:—50 pounds. *Containers*: *box.*
Instructions Received:

Attempt briquetting without binder on hand press. If successful, attempt briquetting on roll press with a minimum addition of water.

The addition of water in quantity is permissible.

Summary of Results:

On hand press it was found that material briquetted very well without any addition of binder or water. The material, however, would not form briquettes at all on roll press, without addition of water. After attempting various percentages of water, it was found that between 18 and 20 per cent of water had to be added to the ore to produce a briquette on the roll press that would not "check" and show cracks. The briquettes obtained were very hard and will withstand hard usage.

To briquette this material properly it was found that a temperature of 100 to 110° F. was necessary to give a proper consistency to the material preparatory to briquetting in roll press. The briquettes had to fall from the press on a chute and then down a very sharp incline on to a belt. This caused the excessive formation of fines. With proper design for removal of briquettes as they come from the press, this fault can be readily obviated.

John Smith,
Chemist.

APPLICATION OF BRIQUETTING TO CHEMICAL ENGINEERING.

The Production of Acid Phosphate from Phosphate Rock by the Volatilization Process.—In the manufacture of phosphate fertilizers, the present widespread practice is to process the rock with sulphuric acid, whence phosphoric acid is extracted. The bulk of our phosphate supplies comes from Florida and Tennessee. The great Western reserve of phosphate deposits have as yet been practically untouched. Latterly in the Florida and Tennessee fields there has been an increasing difficulty in meeting the demand for high-grade rock, which the fertilizer operator requires for the sulphuric acid process. Expensive cleaning methods have been adopted. It has, therefore, been the cause of intense study and research on the part of the Bureau of Soils of the Department of Agriculture to evolve a commercial process based upon the volatilization of phosphoric acid from mixtures of rock, sand and coke by pyrometallurgical methods. In view of the fact that silica is needed in considerable quantity to bring about the chemical reaction resulting in such volatilization, the lower grade phosphate rocks would be available and possibly

necessary. Aluminum compounds are of aid, too (they are a detriment in the old process), for they tend to lower the melting point of the slag.

At first, the electric furnace was employed. It was successful in producing the acid phosphate but at a cost which rendered it of doubtful value. The work then proceeded along the lines of fuel smelting. It was necessary to evolve a special furnace. Such

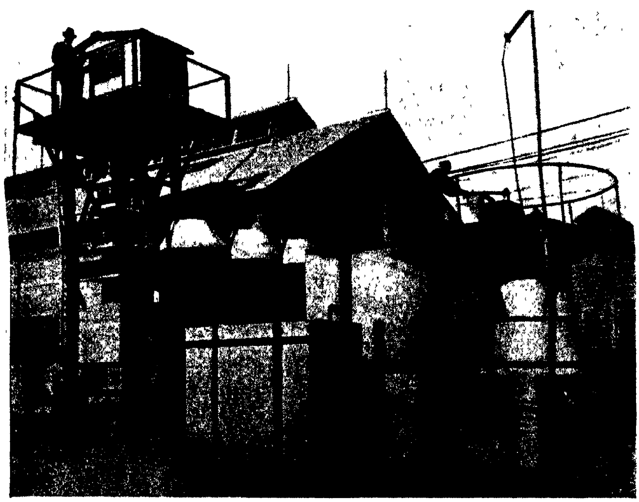

Fig. 155.—Experimental Furnace for Smelting Briquetted Mineral Phosphates. Bureau of Soils, Arlington Farm, Va.

a furnace (illustrated in Fig. 155) was erected at the Government Farm at Arlington, Virginia, of a size to permit operations on a semi-commercial scale. The furnace is built of fire-brick, consisting of a round stack with elongated, butt-shaped slag chamber at the base; at each end of this chamber is a Laylor oil burner operating with high pressure oil and low pressure air. The air is pre-heated and supplied by blowers. The roof of the slag chamber is arched, with a circular opening for the stack. The stack is 6 feet high. At the throat of the chamber where it discharges into the furnace hearth the diameter is 12 inches. At the top of the bosh the diameter is 2 feet, and at the top of the shaft, 14 inches. Capacity is 700 pounds. In operation the furnace is blown in sim-

ply by lighting the oil burners, and when the requisite heat is reached, the first part of the charge is added. The furnace may be warmed up with coke at first. Within a few minutes after the charging, copious fumes of phosphoric acid are given off. These fumes pass through a dust catcher and thence are led through a series of three stoves intended: (a)—to burn the combustible gases coming from the furnace, (b)—to absorb through brick checkerwork the heat so evolved, (c)—to return that heat to the system by using it for pre-heating the oil burner air. From the stoves the gases are led through a brick flue to a Cottrell precipitator where the acid is collected. This precipitator consists of six terra cotta pipes 12 feet long under which is a stone collector for the acid. The slag produced is vitreous, green in color and very abrasive.

The phosphates, sand and rock, are too finely divided to permit of the above process being successful unless nodulizing or briquetting were adopted. It was out of the question to pass the gases through the finely divided material. Briquetting was thought of great advantage to the process because, by intimately mixing the finely ground coke or other form of carbon with sand and phosphates and briquetting the mixture, the reducing agent could be protected against oxidation. In fact, it may be said that the science of briquetting has made the low-cost pyro-metallurgic smelting of phosphate rock a commercial probability. Most of the briquettes used in the Arlington experiments were made upon the hand press illustrated in Figure 153. A considerable tonnage, however, of the briquettes for these runs were made by coal briquetting methods, and it has become quite clear that such methods apply with but little modification. To the rock fines 4 per cent of water was added, and the mix was agitated in the pug mill and masticated. The masticated mix sent to the press returned excellent briquettes, and this without binder. It was found, however, that where transportation is necessary an admixture of 2 per cent sulphite liquor helped very much. Where, however, a briquetting plant for phosphate is working in conjunction with the furnaces described, it is quite clear that no binder will be required. The moisture addition will be subject to the quantity and condition of the moisture already contained in the phosphate. Mr. Waggaman has investigated very thoroughly the mixtures best adapted for the

smelting of the briquetted charge. The sand addition was varied in accordance with the amount of silica in the rock. Experiments were also made to determine the feasibility of substituting soft coal and even peat for the coke admixture. The sand admixture was made with a view of obtaining a silica to lime ratio of 59:41. About 12 per cent coke has been found to be the proper fuel admixture. It is interesting to note that while preliminary experiments indicated that fine grinding gave a greater resisting power in the briquettes, the difference of durability acquired did not pay for the additional expense involved. The final experiments indicated that soft coal could certainly be used to replace the coke in the briquette and that a portion at least of peat could be used. This fact is important in view of the location of peat bogs in the vicinity of the phosphate beds.

While the above process has as yet not been installed on a large scale anywhere, there is little doubt but that the work of Prof. William H. Waggaman, who has conducted these experiments for the Bureau of Soils and is in the main the one to whom the credit is due for its success, will shortly see a wide-spread adoption of the process.

The Tennessee phosphate sands have been briquetted without binder by the same methods as described.

Briquetting Applied to Fixation of Nitrogen.—The raw materials required in the cyanamid method for the fixation of nitrogen (as practised at Muscle Shoals) are limestone, coke and coal. It has been found that the briquetting of these three ingredients making up a charge for the electric furnaces quickens the process very much. On the other hand, briquettes made of the requisite quantities; namely, 55 parts lime, 18 parts coke braize, 24 parts bituminous coal with varying proportions of dehydrated tar as a binder disintegrated in from three to five days because of the action of moisture, from either the air or the binder, upon the lime.

In a research conducted by the Fixed Nitrogen Research Laboratory at Washington it was found that lime briquetted without the coke for the above purpose made a stable briquette when 17 per cent of coal-tar pitch was added or 15 per cent of asphaltic pitch. The coal-tar pitch made the better briquette. In this case, it was, undoubtedly, the intention to submit the lime to the elec-

tric furnace with the coke in lump form rather than briquetted with it. A coal briquetting plant consisting of mixer, masticator and roll press is excellent for the purpose. The following precautions should be observed in briquetting of this nature:

1. The burnt lime must be fresh, and not the least bit air-slaked.

2. It must be ground so that all will go through 10-mesh screen.

3. The lime should be heated to about 200° F. before adding anything to it.

4. The binder may be either asphaltic residue or coal-tar pitch with a melting point between 150° and 170° F.

5. Between 15 per cent and 17 per cent of either of the above binders would be required to produce good briquettes.

6. The binder is added in melted form, and should be thoroughly mixed with the lime.

7. It is essential that the binder be absolutely water-free, and in commercial practice should be melted in a cylindrical tank with a spiral welded steam coil without any fittings.

8. The mixture as it goes into the press should have a temperature of 180° F.

9. At all stages of the process, as little air as possible should be permitted to come in contact with the lime, inasmuch as it not only air-slakes the lime, but causes the production of an inferior briquette unless the binder content is increased to correspond.

10. The finished briquette should be disposed of as soon as produced in order to prevent decomposition due to air-slaking.

The Bucher Process for Manufacturing Sodium Cyanide.—A description of the Bucher Process for the fixation of nitrogen by the formation of sodium cyanide from a briquetted mix of soda ash, carbon and iron catalyzer is detailed by Mr. M. DeKay Thomson in *Chemical and Metallurgical Engineering,* Vol. 26 No. 3, January 18, 1922. Researches in this process were carried on in 1921 for the U. S. Smelting, Refining and Mining Company.

Prior to these experiments difficulty had been experienced in obtaining the full benefit of the reaction

$$Na_2CO_3 + 4C + 2N = 2NaCN + 3CO.$$

The carbon used had been metallurgical coke fines. A concomitant difficulty was the tendency of the briquettes to fall to powder on treatment with nitrogen.

The briquette manufacture was simple. About thirty parts soda ash, about twenty-five parts of iron, and the requisite carbon (petroleum coke gave the best results), were mixed, after moistening, in a Werner and Pfleiderer mixer. The mixture was passed through a meat chopper, and briquettes cut from the pulped mass. The briquettes were dried in covered iron pots, heated with a Bunsen burner.

The briquettes, placed in vertical tubes, were heated in a nitrogen atmosphere. The heat was obtained by passing an alternating current through the pipe, 2,400 amperes when cold, 1,600 amperes when hot— at 10 volts pressure. The pipes were insulated. The exit gas was lighted, being largely carbon monoxide, and the life of this flame indicated the length of the reaction. The temperature was between 940° and 1,040° C. After the CO flame was extinguished, the current was withdrawn and the charge permitted to cool in a current of nitrogen.

As high as 90 per cent conversion to cyanide was obtained during these runs.

Later a small electric furnace, somewhat similar to the Schoeld, was designed and installed, and similar runs made.

These runs were made at the Rogers Laboratory of Physics, Massachusetts Institute of Technology, Boston, Mass. The process described has not yet entered the commercial field.

The same process would be of equal value in the manufacture of calcium carbide.

Another method for the fixation of nitrogen is the invention of Mark Schoeld, which has been acquired by the Armour Fertilizer Works. In this method for nitrogen fixation an electric furnace is used and heat is generated upon a continuous column of coke or other carbon particles with briquettes made from calcined bauxite or other finely divided alumina. The briquetting of bauxite is extremely simple. It is in effect a clay when moistened and a short grinding followed by any pressing operation will make good briquettes. It is probable that the Schoeld process calls for a brick press with a special mold, for the briquette made is in cylindrical form 2 inches in diameter and 1¾ inches long. The

mixture in the electric furnace is composed of approximately 40 per cent of briquettes and the balance 60 to 65 per cent of larger substantial infusible carbon resistors—probably broken electrodes. These larger carbon pieces are about 5 to 6 inches in diameter. In making the briquettes usually 25 per cent of fine carbon is added. The large carbon pieces do not enter into the chemical reaction. They serve to prevent fusion of the briquettes. As the mix-

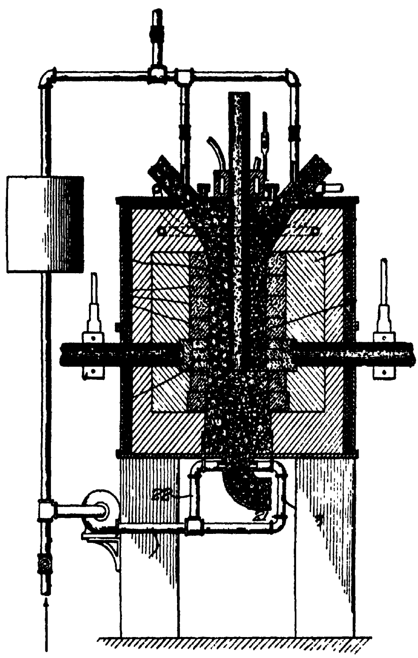

Fig. 156.—The Schoeld Process for the Manufacture of Aluminum Nitride by Electric Treatment of Briquetted Bauxite.

ture travels through the furnace a nitrogen-containing-gas is circulated from the base, the nitrogen being in excess and the direction being opposite to that of the travel of the charge. The heat of the electric furnace produced from stationary electrodes through the charge as a resistor suffices, in connection with the gas current spoken of, to cause the formation of aluminum nitride in the briquettes. The broken carbon can be used again and again.

In Soap Manufacture.—An interesting application of briquetting is that used by the Electro Smelting and Aluminum Company. (This information obtained from a paper by Alfred H. Cowles before the *Eighth International Congress of Applied Chemistry, September 12, 1912*). By this process alumina, hydrochloric acid, caustic alkalis, and a white hydraulic cement can be produced from salt, clay and lime. The salt, clay and lime are mixed in proper proportion in a pug mill, ground in a masticator with the proper amount of moisture and pressed in a tile press so that the briquettes have the shape of a hollow tile with four openings. The briquettes are dried in a kiln and then passed on flat cars through a long tunnel furnace whose maximum temperature is 1035° C. Steam is blown into the discharge end of the furnace. The weight and composition of the material on the cars fed into the furnace are carefully checked and the correct proportional weight of exhaust steam passed into the furnace. From the charging end the gases are taken out by a large blower to the acid-condensing system, whence the acid hydrochloric is obtained. The carbon in the briquettes is consumed. The products of the furnace are hydrochloric acid, water, carbon monoxide and a sodium-silica-aluminate; the latter is still in the form of the briquettes. These residual briquettes are ground and heated with lime. The resultant product is sodium oxide, alumina and di-calcium silicate. To obtain this result the mixture of lime and acid salt is heated in a rotary cement furnace just to clinkering temperature. The sodium oxide and alumina are leached from the clinker and separated by methods in usual practice. The di-calcium silicate remaining as a residue when heated again in a cement furnace with lime gives an excellent iron-free hydraulic cement, which, being white, sells for higher than the market price of ordinary cement. It is claimed that the same process would be of benefit in extracting potash from feldspar.

BRIQUETTING SODIUM CYANIDE

In Germany briquetting is practiced on certain chemicals; such as, sodium cyanide, to facilitate handling in transportation. The briquetting is done without admixture of binder or water under powerful presses. It has not come into vogue in the United States.

BRIQUETTING BROKEN GLASS

Experiments have been made under the auspices of the Edison Lamp Works, Newark, New Jersey, for the grinding and briquetting of waste broken glass; such as lamp globes. Briquettes were made in a Gilmore type horizontal press (described in Chapter II) with an admixture of sodium silicate at 18,000 pounds pressure. The briquettes were excellent, but it is not certain that the operation cost will allow for an installation of this character.

BRIQUETTING SALT

An interesting phase of briquetting is the pressing of evaporated and rock salt into blocks. Salt is mined by two methods: first, by shaft and rooms just as coal is mined, and second, by the oil-well method, wherein a hole is drilled to the rock salt bed and cased. Water is pumped through tubes sunk into the casing, whereby the salt is dissolved, and the brine is pumped to the surface and evaporated. In the case of the mining method, the salt is passed over screens and classified for various purposes.

There is considerable waste in mining. Much loose salt is obtained, which is unsuitable for commercial purposes. Formerly, such salt was allowed to accumulate outside the mine, where the rains washed it out over the land and into the streams. It was found that the formation of this mine waste salt and the evaporated salt into blocks of uniform size and density is of great advantage. The resulting block is excellent material for handling and shipping. Closer packing is possible. The pressed block is ideal for stock-feeding purposes. It has been the practice in stock raising to put crude blocks of salt into the field for the stock to lick at will. The pressed blocks have been found to last longer and to resist the action of weather far better than the natural blocks in the open field or under transit conditions. There are no shale inclusions nor rough edges and the cattle are not likely to cut their mouths. Furthermore, it is possible to add sulphur or other medicines in the fabrication of the block whereby an additional medicinal value is obtained.

The Mueller system for making salt blocks by hydraulic pressure has been in operation at Ebensee, Germany, since June, 1895. The briquettes are made from 2 pounds up to 2½ pounds weight. The operation is as follows:

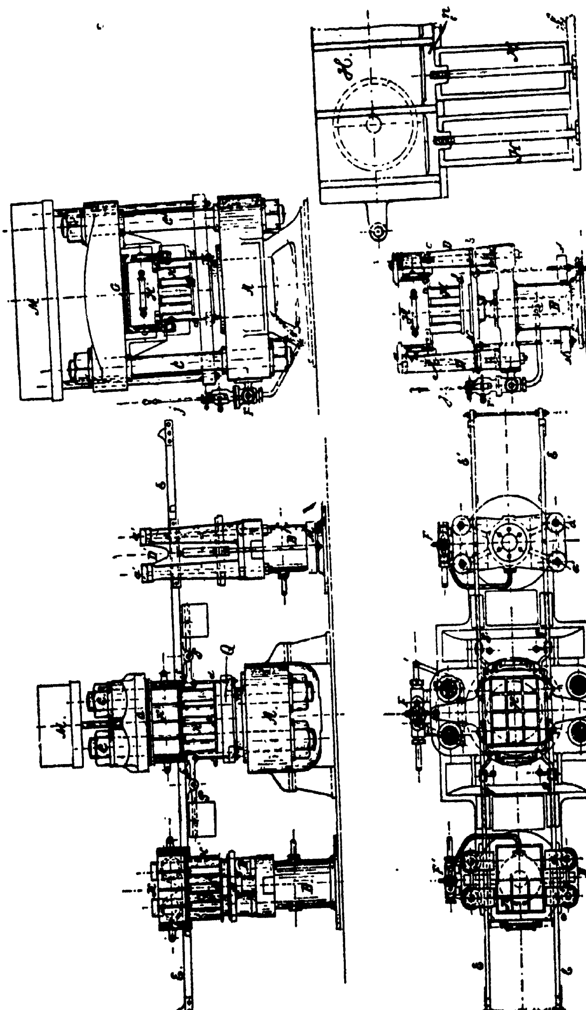

Fig. 157.—Diagram of Mueller Method of Salt Block Manufacture as Practised at Ebensee, Germany.

The salt is dried and but little moisture left therein—just enough to insure a briquetting bond with the least possible chance of corrosion of the molds. The dried salt, in which lumps have formed, is passed through a mixing apparatus, which is provided with a comb-shaped crushing plate made of phosphor bronze. The feeding apparatus to the crushing plate is largely similar to the familiar paddle mixer used in coal briquetting. Thence the salt passes through a classifying screen and is fed into a measuring device, from which it goes to the press molds. The press consists of a series of pressure cylinders with two discharge cylinders located on each side of the pressure mechanism. The pressure and discharge units are united by traveling rails E-E′. The entire mechanism is provided with a double valve F, F′ and F″, controlling the hydraulic flow. This valve is operated by the lever J. The molds are set in form boxes, which slide on rollers over the rains E-E′. Each form box is lined with phosphor bronze. There are twelve molds in each box (in the case of the 2-pound blocks). To each compartment in the form box is attached a plunger made of steel. At the top of each plunger is set a base of phosphor bronze, fitting into the compartment. The plungers extend below and are connected by one steel plate L to which uniform motion is transmitted to all the plungers working upward. The press is provided with a ballast weight M on top. In the operation one set of molds is set above the right discharge cylinder and another at the left. The plungers are at their lowest point and the compartments are ready to receive the salt. A filling box is placed above the molds, its bottom removed, and the salt falls into the molds. The filling box is removed and the nest of molds pushed along the rollers into the press. The water valve F is opened and the piston plate L rises, lifting the mold compartment against the top of the press. Thus the loose salt is pressed into briquettes. After a proper interval, the valve is switched and the mold nest released and carried over to its own discharge cylinder. The molds from the discharge cylinder to the left are filled in the meanwhile and are now ready to enter the pressing mechanism. Thus it is seen the two feed and discharge positions are at work alternately, both serving one pressure system. When the blocks arrive in the discharge cylinder, pressure is again brought to bear by means of the valve, and the finished briquettes

are raised by the plungers above the surface of the mold nest and removed by aluminum members designed to lift all the briquettes at once. Thence the briquettes go to a drying channel and after thorough drying, are stored.

In the method of Theodore Neimke (*Franke—Handbook of Briquetting*) ground rock salt is moistened with water and mixed with 0.75 to 1 per cent magnesium oxide. The pressure is applied by any suitable plunger press. The briquettes are dried at between 80 and 100° C. The addition of magnesia permits the use of much lower pressures, and the resultant briquettes are very hard and resistant to the action of the atmosphere. In France briquettes have been prepared for overseas export to Guiana.

Fig. 158.—Salt Briquettes in Storehouse. American Salt & Coal Co., Lyons, Kansas.

The Hohensalza Rock Salt Company has manufactured a stock-feeding briquette from a mixture of rock salt, iron oxide and wormwood powder. The mass is stamped in a mold into briquettes and slowly heated in a chamber kiln.

Flat salt briquettes made from the purest salt were used by the German troops.

In America it has been the consensus of opinion that the blocks should be larger and subjected to far higher pressure than those made abroad. A 50-pound block is considered desirable. A typical American installation is that of the American Salt and

Coal Company at Lyons, Kansas. The salt is crushed and dried very thoroughly and thence is passed to a battery of three hydraulic salt-block presses made by the Hydraulic Press Company. The principles of operation of this press are similar to those of the Stevenson-Little press described in Chapter II. The blocks weigh 50 pounds each. The presses have a pressure capacity of 1,000 tons exerted upon a block 8 x 8 x 12 inches, or about 20,000 pounds per square inch. The loose salt is placed in a floating die supported by springs. The

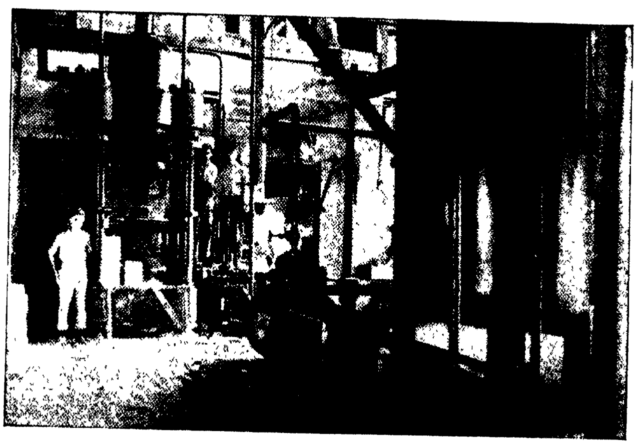

Fig. 159.—Making Salt Briquettes. American Salt & Coal Co., Lyons, Kansas.

pressure is applied from the main cylinder, the plunger descending from above. After the pressure stroke, the ram is turned by means of an auxiliary ram located at the top of the press and the fluid is returned to a surge tank. The mold cylinder is raised by springs, leaving the briquette below. The operation is controlled by two hydraulic valves. The salt is transported from the press into ware rooms and stored for shipment. At this plant the blocks are made from both the ground rock salt and the evaporated salt, but the former are considered the purer and better.

Cement Rock Briquetting.—There is a very earnest effort on the part of at least two cement companies to substitute a stationary stack method for making cement for the familiar rotary kiln. As the use of a stack involves the passing of hot gases through the

raw cement mix, it is obvious that the mix must be in lumps to permit the passage of the gas. It has been found that the addition of water in quantities varying from 7 to 12 per cent to the cement mix, made thoroughly homogeneous by proper equipment, gives a texture to the material that admits its passing into a roll press with the formation of fairly strong briquettes. The briquettes can be strengthened, if necessary, by the addition to the mix of a small quantity of Portland cement, which, of course, being made on the ground, is available at very low cost. While no large installations have as yet been made, the situation is full of promise. It is claimed that such a method of cement-making will materially reduce costs and will admit of a purer product.

BRIQUETTING APPLIED TO ARTIFICIAL STONE

Many of the presses outlined in Chapter II have been used in the manufacture of artificial stone, but though the methods are in many cases similar to those described, work of this nature ought really to come under the scope of brick-making and does not come properly into this volume.

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BRIT. P.	No. 156,479 to Nitrogen Products Company—Jan. 5, 1921.

APPENDIX.

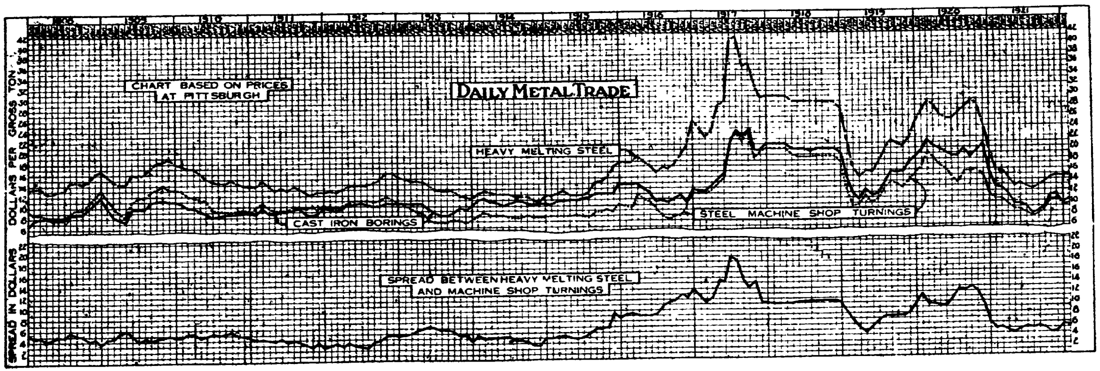


CHART I.—Analysis of price fluctuation of heavy melting steel, cast borings and steel machine shop turnings, 1908–1921 inclusive [As $1—$2 per ton over heavy melting steel price is paid for steel briquettes, the "spread" shown in Chart II may be taken as permissible briquetting cost]. Courtesy of *Daily Metal Trade*.

TABLE XIX.—BRIQUETTING PLANTS OPERATED IN THE UNITED STATES IN 1921

Group	Name and address of operator	Location of plant	Date put in operation	Raw fuel used
Eastern States:				
New Jersey . .	Burnrite Coal Briquette Co., 543 New Jersey Avenue, Newark, N. J.	Newark	1920	Anthracite
Do.	Fuel Briquette Co., 520 Brunswick Avenue, Trenton, N. J.	Trenton .	1918	Do.
New York . .	General Briquetting Co., 25 Broad St., New York, N. Y.	New York .	1920	Do.
Pennsylvania .	American Briquette Co., Drexel Building, Philadelphia, Pa	Lykens . . .	1920	Do.
Do. . .	Anthracite Briquette Co, Sunbury, Pa	Sunbury .	1919	Do.
Do	Lehigh Coal & Navigation Co, 437 Chestnut Street, Philadelphia, Pa.	Lansford . .	1909	Do.
Do.	Scranton Anthracite Briquette Co, Dickson City, Pa	Dickson City	1907	Do.
Virginia . .	Clinchfield Carbocoal Corporation	South Clinchfield	1921	Coke made from high-grade bituminous coal
Do . . .	Delparen Anthracite Briquette Co., Parrott, Va.	Parrott . . .	1915	Virginia semi-anthracite
Central States:				
Missouri . . .	Standard Briquette Fuel Co. 310 N. Fourth St., St. Louis Mo	Kansas City	1909	Arkansas semi-anthracite
Wisconsin . .	Berwind Fuel Co, 122 South Michigan Ave, Chicago, Ill.	Superior . .	1912	Semi-bituminous slack
Do.	Stott Briquette Co, Merchants' National Bank Building, St Paul, Minn.	Do	1909	Anthracite fine and bituminous slack
Pacific Coast States:				
California . .	Los Angeles Gas & Electric Corp., 645 South Hill Street, Los Angeles, Calif.	Los Angeles	1905	Carbon (petroleum residue)
Oregon	Portland Gas & Coke Co., Gasco Bldg., Portland, Ore.	Portland .	1913	Do.
Washington .	Pacific Coast Coal Co., 612 L. C. Smith Bldg., Seattle, Wash.	Renton . . .	19 4	Bituminous slack and sub-bituminous coal

From "Fuel Briquettes in 1920." W. F. McKenney. Mineral Resources of the United States, Part II.

TABLE XX.—FUEL BRIQUETTE PRODUCTION IN IMPORTANT PRODUCING NATIONS IN 1920

	Tons	
United States of America		
Eastern States	258,621	
Central States	212,176	
Pacific Coast States		
(Including oil carbon briquettes)	96,395	
Total		567,192
Canada		
Alberta	101,922	
Eastern Province	20,393	
Total		122,415

	Tons
Great Britain (mainly from Swansea and Cardiff) (For 11 months ending Nov., 1921,—743,682 tons)	2,258,111
France	2,058,497
(The consumption in France amounted to 4,755,492 tons of which 887,179 tons came from Great Britain, 967,000 tons from Germany, 158,628 tons from Belgium and the balance from other sources. (The Saar district supplied 14,469 tons). France in 1920 exported 42,839 tons coal briquettes).	
Spain	742,408
Holland	634,000
Belgium	2,922,363

[The production in Belgium ran very evenly month by month without seasonal differences. In July, 258,222 tons were produced—in December 267,070. Belgium imported 151,700 tons during the year, and exported 215,200 tons. 2,138 persons are employed in the fuel briquette business in Belgium. (Dec., 1920)].

	Coal briquettes (steinkohle) Tons	Lignite briquettes (braunkohle) Tons
Germany		
Upper Silesia	66,000	819,000
Lower Silesia	290,000	
Halle	17,000	12,263,000
Clausthal	80,000	93,000
Dortmund	3,577,000	
Bonn (without Saar)	147,000	6,662,000
All Prussia (without Saar)	4,177,000	19,837,000
Bavaria (without Palatinate)		121,000
Saxony		1,808,000
Baden	669,000	
Hesse	82,000	18,000
Brunswick		624,000
Sachsen Altenburg		1,715,000
Anhalt		158,000
Balance of Germany	11,000	
Total	4,939,000	24,281,000

[The Saar district produced 33,461 tons in 1920. (In January, 1921, Germany delivered 96,698 tons braunkohle briquettes to the Allies)].

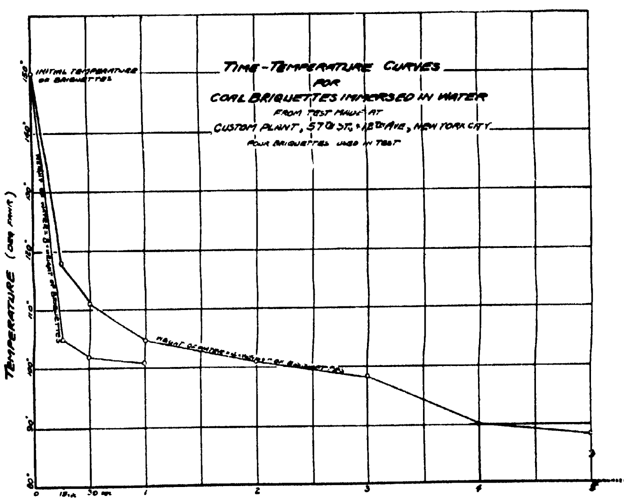
	Coal briquettes Tons	Lignite briquette Tons
Czecho-Slovakia	70,734	63,509

TABLE XXI.—IMPORTS OF FUEL BRIQUETTES INTO SWITZERLAND IN 1920

	Tons
From	
Germany	82,986
Great Britain	281,134
France	6,219
Belgium	18,000
Holland	4,892
United States	7,254
	400,485

(*N. B.* Switzerland is not a coal producing country).

CHART II.



Rate of cooling coal briquettes (asphalt binder) by water immersion.

TABLE XXII.—LIGNITE UTILIZATION BOARD OF CANADA—SUMMARY OF BINDER EXPERIMENTS

Minimum binder ratios given below are comparative only and are not to be construed as representing possible commercial practice

Material briquetted	Volatiles, %	Hardwood tar, etc.: Soft tar-30A	Hardwood tar, etc.: Pitch, 392° F. up,-30A	Hardwood tar, etc.: Pitch and lignite oils †	Coal tar and pitch: Soft tar	Coal tar and pitch: Pitch, m. p. 145° F.	Coal tar and pitch: Pitch, m. p. 190° F.	Coal tar and pitch: Pitch and lignite oils †	Asphalt and pitch: Soft (liquid) asphalt. LR(B)3	Asphalt and pitch: Oil pitch, m. p. 172° F. LR(b)	Asphalt and pitch: Oxidized oil pitch, m. p 200° F., and lignite oils †	Sulphite liquor: Liquor, 50% solids	Sulphite liquor: Liquor and lignite oils †	"Hite" binder; flour and lignite pitch, 1 to 1 ‡
Heat treated—smokeless and non-softening														
Anthracite	43		5.5–6		35+	5.5–6.5				6–7		10–12		3.7–4.5
Lignite, air dried		20–25	20+											
Lignite, oven dried	38.5	18–20	18–19		30–35		30–35							
Lignite, residue, 662° F.	27.5	15–18	16–18											N. G.
Lignite residue, 842° F.	17.0		14–15			16+								N. G.
Lignite, residue, 1,050° F.	9.5	13–14	11	8–10	18–20	13–13.5	11–12	9–10	20+	12.5–13	9–10	18–22	10–15	N. G.
Lignite, residue, 1,430° F.	4.5		8.5–9.5			12–13								7.3–7.7
Lignite, residue, 1,700° F.	2.5		8.5–9.5			11–13	10.5–11.5							6–6.5
Not heat treated—smoky and softening														
Anthracite						4.5–5.5				5–7				3–3.5*
Lignite residue, 1,050° F.	9.5	12–13*	10	8–8.5		11–12	10.5–11	8.5–9		11–11.5	8.5–9	15–18*	9–10*	6–7*
Lignite residue, 1,430° F.	4.5		8–9			11–12								
Lignite residue, 1,700° F.	2.5		8–9			11–12	10–11							5–5.5*

† Binder ratios do not include lignite oil. ‡ Binder ratios based on flour plus pitch. * Not waterproof.

TABLE XXIII.

HOUSE HEATING TEST

Lignite Utilization Board of Canada. April 1, 1921.

		Carbon lig. briquettes.	Anthracite coal.
1.	Duration of test days.	21⅓	44⅔
2.	Min. outside temp. noted, °F.,	-20	-7
3.	Max. outside temp. noted, °F.,	+42	+44
4.	Av. difference of temp. inside and out, °F.,	46.5	47.5
5.	Total fuel fired. net lbs.,	2504	5272
6.	Av. daily charge. lbs.,	117	118
7.	Av. no. of charges per day,	3.8	3.1
8.	Av. fuel per charge, lbs.,	30.5	38.2
9.	Av. daily ash, lbs.,	17.7	32.0
10.	Calc. combust. in ash, %,	—	40
11.	Calc loss of fuel in ash, %,	—	11
12.	Ash removed, %,	15.1	27.1
	Analysis:-		
	Moisture, %,	4.3	2.6
	Ash, %,	16.5	16.1
	Volatiles. %,	19.5	5.6
	Fixed carbon, %,	59.8	75.7
	Sol. in CS_2,	13.0	—
	B. t. u. per lb.,	11290	11770

Test made by E. S. at his own residence, 69 Cameron Street, Ottawa, Ont., in winter, 1920-1.

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